VOLUME II

FINAL ENVIRONMENTAL IMPACT STATEMENT

Eastern Powder River Coal Basin of Wyoming

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This is Volume II. It contains Chapters V through XI of Part I, the regional analysis.

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REGIONAL ANALYSIS

CHAPTER V

PROBABLE CUMULATIVE REGIONAL IMPACTS

The analysis developed in this environmental impact statement is based on 1990 projections. The cumulative environmental impact is quantified, to the extent possible with existing data, only to this time period. The probability is recognized that, based on current leaseholds and investments, the pattern of resource development and growth will continue after 1990, though at modest rates. Cumulative environmental impacts will also increase but will be of variable quantity as indicated in the assumptions and criteria for analysis. While further projections and predictions are possible with ever decreasing levels of confidence, the time frame and geographic area parameters (Chapter I) were established at the outset of the analysis. If differences occur over time, the impacts analyzed in this section can be scaled up or down through use of the assumption and analysis guidelines (Chapter II). This will provide a better picture of the developing situation.

If the magnitude is scaled upwards, impact on certain environmental components would probably be more than on others. Those most likely to be affected are: air quality, soils, water resources, vegetation, wildlife and fish and agriculture.

In the impact chapters of the regional and site specific analyses, it must be strongly emphasized that the full impact on the environment, whether singular or cumulative, is quantified or qualified to the fullest extent assessible without imposing any management constraints that would mitigate, minimize, negate or divert these effects as they pertain to the proposed action(s). Such an evaluation is made with the recognition that certain results will not occur since they are precluded by agency resource management responsibility. The full report, in other chapters, contains

the required and probable mitigating measures to be applied if the proposals are approved along with impacts which cannot be feasibly avoided.

Projected development to the year 1990 within the study area will consist of: ten mines with plans to produce 296 million tons of coal by 1980, increasing to 12 mines, 858 million tons by 1985 and 14 mines and 1,543 million tons by 1990; construction and operation of a 330-megawatt air-cooled power plant, and a 250-million cubic feet per day gasification plant by 1980, a 450-megawatt air-cooled and a 500-megawatt water-cooled power plant as well as a second 250 cubic feet per day gasification plant by 1985 and another 500-megawatt water-cooled power plant by 1990; construction of 16 miles of road, 44 miles of powerline, 30 miles of coal slurry pipeline, 140 miles of rail line by 1980, 20 miles of road, 164 miles of powerline, 145 miles of rail line by 1985, and 24 miles of road, 225 miles of powerline and 150 miles of rail line by 1990, all of which will cause various impacts on the environment and its individual components.

Employment, construction and permanent, resulting from these developments will cause population increases of: 27,000 by 1980, 42,000 by 1985 and 47,000 by 1990 in the study area. These increases in population will require associated facilities such as schools, sanitary land fills, sewage plants, increased social services, all having additional environmental impacts. Population in the surrounding six-county area is projected to increase only moderately: 10,000 by 1980, 11,000 by 1985, and 13,000 by 1990.

It is acknowledged that not all environmental impacts associated with this development are confined to the State of Wyoming. If coal is exported from the study area to such places as Arkansas, Colorado, Illinois, Indiana, Iowa, Kansas, Louisiana, Nebraska, Oklahoma and Texas, impacts

from energy conversion will occur in those areas. The exact nature of these impacts is not reasonably foreseeable due to the inability to fully anticipate how and under what conditions the coal and energy will be utilized. It should be noted that the impacts resulting from consumption of coal in electric power plants outside of the study area may be similar to the impacts of consumption of coal for electric power generation within the study area, varying essentially with respect to the degree of impact in relation to environmental conditions existing in those areas. Environmental impact of the use of coal and energy developed in the study area will be analyzed at the time other major federal actions are required or as necessary in these states to meet their environmental quality act requirements.

Climate

Development of a number of coal mines, power plants and gasification plants, and disturbance of significantly large areas of land surface may cause significant changes that could detrimentally affect weather and climate.

Recent studies indicate that large urban-industrial areas do affect precipitation. However studies have not been conducted in semi-arid climates; therefore, potential effects are inferred from theoretical relationships and knowledge concerning precipitation mechanisms and studies of climate modification in other areas.

Two potential major consequences of large scale energy development may lead to significant inadvertent modification of the regional weather and climate. These are increases in atmospheric particulate loading and changes in natural land surface characteristics which affect the precipitation mechanism.

Some evidence indicates that changes of atmospheric particulate loading and alteration of the earth-atmospheric energy balance may contribute to creation of drought conditions in semi-arid climates (Charlson and Pilat 1969; Bryson 1972; Mitchell 1971; Huff, Changnon 1973). Reduction in precipitation could have severe affects on agricultural productivity, mined land reclamation and water supplies within the region.

Air Quality

Complex source air pollution

Development of numerous coal mines, power plants, residential areas and disturbances of large areas of land will create multiple sources of various air pollutants. Since air pollutants originate from many sources, effective control would be more difficult than if a single pollution source were involved.

Development actions as outlined could generate dust and other suspended particulate matter from physical activities and chemical pollutants such as hydrogen sulfide, sulfur oxides, nitrogen oxides, carbon monoxide, photochemical oxidants, hydrocarbons, trace elements and radionuclides from processing operations. These pollutants from complex sources may have an adverse impact on existing air conditions in and adjacent to the study area. Impacts could increase rapidly during the period of 1974 to 1980 (seven new mines, a new 330-MW power plant, a gasification plant, 27,000 increased population, 230 miles of new rail line, roads, pipelines, powerlines, with 8,900 acres disturbed) and 1980-1985 (two new mines, two new power plants, one new gasification plant, 15,000 more people, 129 more miles of roads, rail line, powerlines and 10,900 more acres disturbed) and possibly level off during the 1985 to 1990 time period (two more mines, one more power plant and 5,000 more people, and 9,200 more acres disturbed).

Plant stack emissions

Potentially, the most serious cumulative impact on air quality, with possible adverse impact on humans, animals and vegetation, is from stack gases emitted by four new coal-fired power plants and two coal gasification plants. Emissions include sulfur oxides, nitrogen oxides, carbon monoxide, hydrocarbons, hydrogen sulfide, photochemical oxidants and particulates.

Projected development during the period of 1974 to 1980 shows construction of a new 330-megawatt (MW) power plant at Wyodak and retirement of

units 1, 3 and 4 of the Neil Simpson Station. Assuming the new plant and Neil Simpson Unit 5 (20-MW) meet New Source Performance Standards (NSPS), projected annual emissions at Wyodak could be: 1,600 tons of particulates (P), 15,700 tons of sulfur dioxide (SO_2), and 12,400 tons of nitrogen oxides (NO_x).

During this same time period construction of a coal gasification plant to produce about 250-million cubic feet per day is expected. This plant (with 325-MW companion power plant) is expected to produce yearly, 23,800 tons of sulfur dioxide, 11,400 tons of nitrogen oxides, 39,500 tons of hydrocarbons (HC), and 2,100 tons of particulates. (Assuming compliance with NSPS and Wyoming Air Quality Emission Standards.)

By 1985 projected development will include a new 500-MW power plant, and a 450-MW power plant at Wyodak which could produce an estimated yearly emission of 4,400 tons of particulates, 40,400 tons of sulfur dioxide, and 30,600 tons of nitrogen oxides. Also a second coal gasification plant is projected by this time. This plant will have a type and amount of emissions similar to the plant projected for the 1974 to 1980 time period. (Assuming compliance with NSPS and Wyoming Air Quality Emission Standards.)

Another 500-MW coal-fired power plant is expected to be in operation by 1990. This plant is expected to have emissions of 2,300 tons of particulates, 21,400 tons of sulfur dioxide, and 16,100 tons of nitrogen oxides. (Assuming compliance with NSPS and Wyoming Air Quality Emission Standards.)

Some projected potential cumulative emissions during the period 1980 to 1990 are shown in Table 1. Quantities are based on the assumption of new power plants (other than at Wyodak) of 500-MW size, 250 million cubic feet/day gasification plants, and emissions meeting maximums permitted under New Source Performance Standards for Steam Generators, and Wyoming Air Quality Emission Standards.

Based on expected siting of new plants, the areas near Gillette (two power plants and one gasification plant) and Douglas (one gasification plant) could be adversely affected by cumulative stack emissions. With a prevailing northwest wind direction (upper level), other towns that could be impacted by such emissions include Moorcroft, Lusk, Newcastle, Guernsey, Torrington, Wheatland, and Sundance, Wyoming; Custer, South Dakota; and Scottsbluff, Nebraska. However, most impacts would likely occur within 10 to 20 miles of the plant sites, where pollutant concentrations are usually highest, and this would make Gillette and Douglas most vulnerable.

Vehicle and equipment emissions

Industrialization of the study area and attendant population increase (27,000 by 1980, 42,000 by 1985, 47,000 by 1990) will increase use of internal combustion engines of all types. Engine emissions will result in the addition of carbon monoxide, hydrocarbons, particulates, nitrogen oxides and sulfur oxides to the basin air. These emissions are potentially harmful to the health of basin residents, vegetation and animal life. Much of the vehicle and equipment emissions will be contributed by railroad locomotives. Table 2 gives some estimated cumulative locomotive emissions for 1980, 1985, and 1990.

Dust and similar particulate matter

Increases in airborne dust and similar particulate matter (coal dust, fly ash dust, etc.) will result from described development activities. The increased possibility of coal fires and wildfires will increase the possibility of additional toxic pollutants in the air, especially from coal fires. Pollutants resulting from coal fires will be similar to those from a coal-fired power plant.

Airborne particulate matter could reduce visibility and possibly cause traffic accidents during periods of inversions and periods of high winds.

Table 1

Some Potential Cumulative Emissions in the Study Area

	Emissions by Year - 1,000 tons per year											
	1980				1985				1990			
	P	SO_2	NO_x	HC	P	SO_2	NO_x	HC	P	SO_2	NO_x	HC
Dave Johnston P.P. (750-MW*)	3.5	30.6	24.2		3.5	30.6	24.2		3.5	30.6	24.2	
Neil Simpson P.P. (20-MW**)	0.4	1.4	1.3		0.4	1.4	1.3		0.4	1.4	1.3	
Wyodak P.P. (new 330-MW***)	1.2	14.3	11.1		1.2	14.3	11.1		1.2	14.3	11.1	
Wyodak P.P. (new 450-MW#)					2.1	19.0	14.5		2.1	19.0	14.5	
First new 500-MW P.P.#					2.3	21.4	16.1		2.3	21.4	16.1	
Second new 500-MW P.P.#									2.3	21.4	16.1	
Panhandle Eastern Gasification P.##	2.1	23.8	11.4	39.5	2.1	23.8	11.4	39.5	2.1	23.8	11.4	39.5
Second Gasification Plant ##					2.1	23.8	11.4	39.5	2.1	23.8	11.4	39.5
Cumulative Totals	7.2	70.1	48.0	39.5	13.7	134.3	90.0	79.0	16.0	155.7	106.1	79.0

*Existing power plant -- assumption that retrofit program for particulate control will be completed by 1977.

**Existing power plant -- Unit 5 only (Units 1, 3 & 4 to be retired in 1977).

***Source of data for new power plant -- Environmental Report dated May 1973, Black Hills and Pacific Power and Light Companies.

#Emissions for new power plants based on maximums permitted under compliance with New Source Performance Standards (NSPS) for Steam Generators and Wyoming Air Quality Emission Standards.

##Emission estimates include companion 325-MW power plant; estimates based on compliance with Wyoming Air Quality Standards.

P-particulates SO_2-sulfur dioxide NO_x-nitrogen oxides HC-hydrocarbons

Year	Coal Hauled		Diesel Fuel	Estimated Cumulative Emissions-tons per year***				
	Unit Trains/year*	Million tons/ year	per day- 1000 gals.**	Particulates	Sulphur Dioxide	Nitrogen Oxides	Carbon Monoxide	Hydro- Carbons
1980	4,364	48	58.3	266	606	3,937	1,383	1,000
1985	6,182	68	84.1	384	875	5,679	1,995	1,443
1990	8,455	93	112.5	513	1,170	7,597	2,669	1,930

*Loaded trains. Same number of empty trains would be required.
**Fuel requirements include loaded and empty trains.
***Assumed to operate 365 days per year. Also includes loaded and empty trains.

Source: Environmental Protection Agency, Compilation of Air Pollutant Emission Factors, Table 3.2.2-1 EPA Publication No. AP-42, April 1973.

Table 2

Estimated Cumulative Emissions from Locomotives in the Study Area

High winds are frequent but inversions over two-day periods may occur as many as 15 times per year. Particulate matter could also contribute to human allergies and similar irritations and coat vegetation with potentially harmful chemicals.

Based on the prevailing upper level wind direction (northwest), the impact from the increased airborne particulate matter could affect the communities and towns of Gillette, Moorcroft, Douglas, Lusk, Newcastle, Guernsey, Torrington and Wheatland, Wyoming; and Scottsbluff, Nebraska.

Summary

Identification and quantification of impacts with precision is not possible until each system has been designed and a quantitative analysis performed. Prior to construction of each of the facilities, such an analysis will be conducted. However, based on assumed rate and type of development certain qualitative impacts can be predicted for the study area.

Industrialization and development of the study area will result in a decline in ambient air quality. A general decline will occur from 1974 to 1980, with a more serious decline during the 1980 to 1985 period. The rate of decline is expected to level off after 1985, since by this time the major projected development will have leveled off with only minor increases proposed for the 1985 to 1990 time period. The decline of air quality will remain fairly constant for the rest of the time period (1985-1990).

Increased plant stack plumes and haze from disturbed soil and coal dust will result in poorer visibility within the basin and possibly in areas to the east and southeast of the basin.

Emissions could cause localized damage to vegetation and animals over a long time period. Damage to ponderosa pine after exposure to SO_2 has been reported (HEW, Air Quality Criteria for Sulfur Oxides, January 1969). Similar vegetation is found in the Black Hills National Forest around Newcastle and

Sundance, Wyoming and Custer, South Dakota; the northeast portion of the Thunder Basin Grassland in the vicinity of Upton and Osage, and in the Rochelle Hills area. Ponderosa pine is prevalent in these areas. The Upton and Osage areas already experience a reduction in air quality due to emissions originating from betonite plants in the vicinity. Addition of emission from the study area may compound the impact in that vicinity. Effects of emissions on vegetation and animals are not well understood at this time, and research efforts are underway to determine possible adverse effects.

Trace elements, including radionuclides, contained in coal burned by power plants in the study area may be released with stack emissions. Such emissions could have a detrimental effect upon soil, vegetation, animals, and man although little scientific information exists as to their effects on the environment.

An increase in atmospheric sulfur is believed to have resulted in acid precipitation in the northeastern United States as reported by Likens and Bormann (1974). Emission of sulfur dioxide (SO_2) by power plants and gasification plants proposed for the study area could cause a similar problem in the study area and have an adverse effect on the environment, including plants, fish, and metal structures (as reported by Likens and Bormann). However, this is not considered likely.

Photochemical oxidants (smog) may be formed when nitrogen oxide emissions from power plants combine with certain hydrocarbon emissions from gasification plants and sunlight. This pollutant may form from proposed power and gasification plant emissions.

Emissions could have injurious and toxic effects on humans working or living in the vicinity of power and gasification plants in case of accidents or during periods of severe or repeated inversions. Throughout the basin there is a probability of a two-day inversion occurring 15 times per year, and a

five-day inversion occurring four times a year. (Observations by Marwitz indicate persistent winter inversions -- Hearings statement 6-26-74.) Impacts on health could result from long or repeated exposures to any severe air contamination during inversion episodes.

Present ambient air quality in the study area is good, but it will decline with the development of complex pollution sources as industrialization takes place.

Topography

The removal of coal during mining operations will decrease altitude of the land surface to varying degrees and thereby locally create sharper relief or flatten the slope of the land. New landforms will emerge from coal removal owing to placement and type of reclamation of spoil materials and to erosion and redeposition of spoils. Surface mining will increase soil movement, change drainage patterns and size, shape, and position of topographic features. Spoil ridges from mine cuts will be subject to erosion, and erosion may increase locally within pits. Both water and wind are active agents of erosion and deposition and require some form of control in the vicinity of mining operations.

Mining of coal, 296 million tons by 1980, 858 million tons by 1985 and 1.5 billion tons by 1990, will significantly impact the topographic shape of the area mined to recover this coal. By 1990 surface mining will have impacted an estimated 14,000 acres. Each year the slow pace of mining thick coal, even at a high annual rate of 118 million tons, alters only a small fraction of the area that will be disturbed. For example, large mining operations which remove coalbeds about 60 feet thick to produce 17 1/2 million tons of coal annually would disturb only about 165 acres per year. At any period about 445 acres, dependent upon the amount of overburden prestripping necessitates and excluding roads and facilities, would be disturbed by each mining-reclamation operation. Such a situation could comprise 100 acres being prestripped, 165 acres being mined, and 165 acres being smoothed and reseeded. With an estimated production of 118 million tons of coal per year, an average of seven operating mines could annually disturb as much as 3,000 acres in a single year, but over a 15-year period, probably not more than an average of 1,200 acres.

The surface would also be altered, but to a lesser degree, by construction of 24 miles of new roads and 150 miles of new rail lines by

1990. Disturbances from this type of activity will involve about 3,600 acres by that year. Some alteration of land surface will also result from construction of gasification plants, power plants, and reservoirs. Mining and removal of clinker, sand, and gravel to meet construction needs of these activities will also cause minor changes to the land surface. Acreage impacted by this construction is indeterminate at this time.

The removal of coalbeds, ranging in thickness from 20 feet to 120 feet, will result in an overall lowering of the land surface on which this removal takes place. The average overburden thickness which covers the coal ranges from a few feet to 200 feet. During mining, the overburden is broken up and turned over which increases its volume by 20 percent. This increase in volume, however, is not enough to compensate for the removal of thick coalbeds. Figure 1 gives an example of the decrease in altitude which could result from coal removal. In Part A of Figure 1 the overburden averages 149 feet and the coal seam averages 100 feet for a total thickness of 249 feet. The 100 feet of coal is removed. The overburden is increased 20 percent in volume or from an average thickness of 149 feet to 179 feet. The corresponding decrease in altitude of the land surface is the difference between coal thickness (100 feet) and the increased volume (30 feet) or 70 feet. Some coal remains with the spoils because of mining tolerances (90 to 95 percent recovery of coal); thus, this example of 100 percent coal recovery produces a maximum depression.

A reduction in altitude of the land surface can occur wherever coal is mined. Some average altitude changes in the coal mining area from north to south in the study area are about 54 feet at the North Rawhide mine (see Part IV), about 68 feet at the Wyodak mine (see Part VI), about 36 feet at the Black Thunder mine (see Part III), about 38 feet at the

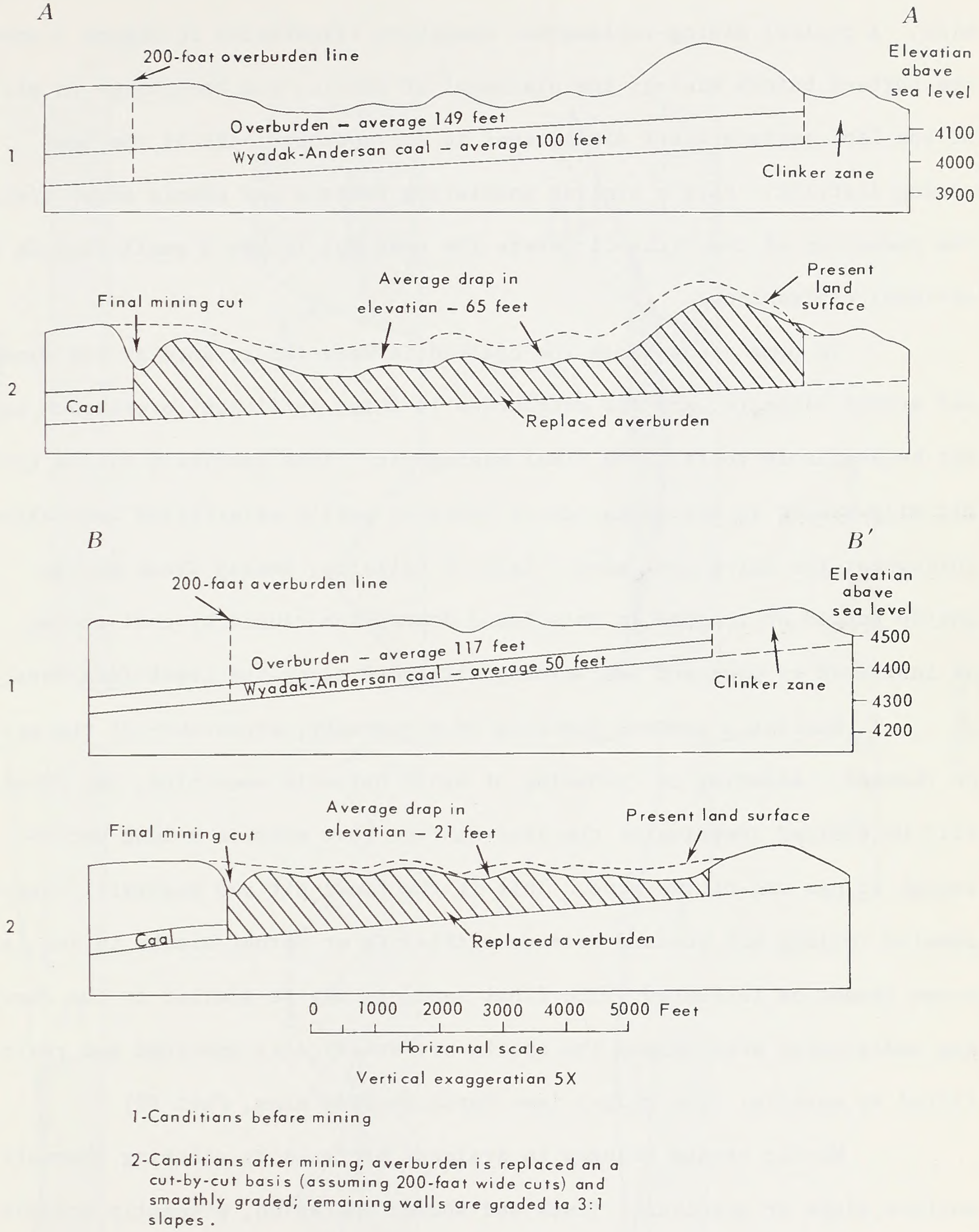


Figure 1

Diagrammatic Sections Showing Potential Changes in Topography Resulting From Surface Mining

Jacobs Ranch mine (see Part V), and about 28 feet at the proposed Rochelle mine. A typical mining-reclamation operation illustrated in Figure 2 shows the surface before mining, the placement of spoils, and the change in altitude of the land surface after mining coal in the southern part of the coal mining district. Here a similar undulating surface may remain after mining. The reduction of the highwall covers the coal but leaves a small lake in a residual depression.

In some areas where the coalbed is very thick, such as the Wyodak bed around Gillette, and the overburden is thin, sufficient overburden may not be available to fill the final mining pit. This partially filled final pit will result in the formation of lakes or partly waterfilled depressions throughout the thick coal area. East of Gillette, Donkey Creek may be partly ponded or trapped in this broad depression caused by coal mining as indicated by pre- and post-mining altitudes along the creek (see Part VI).

Besides a general lowering of topography, appearance of the area may be changed. Assuming no reshaping of spoil but only smoothing, the result will be a broad lowering of the land surface that ends in a long narrow trough at one end of the mine. This is the final pit and highwall. Terrain remains rolling but subdued because cliff-life or abrupt breaks in the landscape cannot be recreated. The final landform may be similar to the surrounding undisturbed area unless the spoils are drastically smoothed and ravines filled by material from ridges (see North Rawhide mine, Part IV)

Mining causes changes in drainage patterns by altering channels and surface slope or gradient. Truck and shovel operation, presently considered by most of the mining companies, produces a smoother, lower-gradient terrain that is locally more favorable to revegetation and decreased erosion. This type of mining operation affects a smaller area per year, results in closer

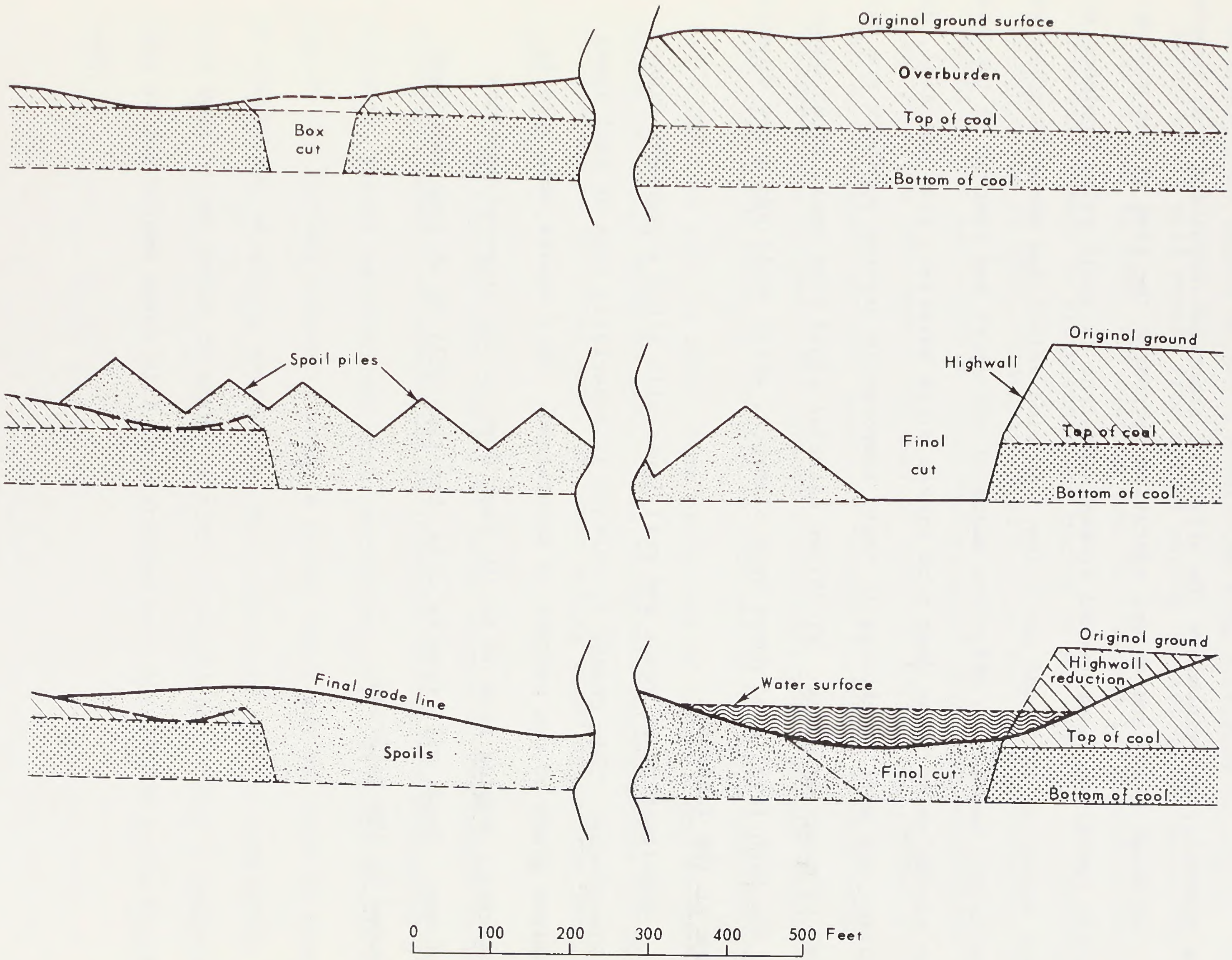


Figure 2
Typical leveling of spoils and change in altitude of the land surface after mining coal in southern part of the coal mining district

control of the final surface altitude and allows optimum recontouring after mining. The smooth terrain decreases channeling and headward erosion of existing channels, and minimizes the effect of sheetwash resulting from thunderstorms. Although truck and shovel operation decreases the size of the mining-reclamation operation, unprotected broken sandstone in spoil piles produces an available source of fine sand particles. At wind velocities above 20 miles per hour, saltation becomes an effective means of transport and removal of the sand. Wind can easily erode loose dust from broken playa material, road material, bare spoil piles, and soil stockpiles if these temporarily exposed surfaces are not protected by water or grass. Windblown material could form small local dunes, such as the high level sand dunes near Glenrock, which would add a new dimension and shape to the landscape.

Construction of roads and rail lines will alter topography along the rights-of-way. This change in surface is especially true of rail lines if a maximum grade of one percent is maintained. This causes deep cuts in the landscape, ranging from 40 to 102 feet deep on the proposed mainline right-of-way. Roads will require cuts, but they will be of less magnitude than caused by the railroad.

Soils

Development of coal resources and attendant facilities will cause a significant impact on soils within the area disturbed by mining. The major impact will result from actual mining operations to remove 296 million tons of coal by 1980, 858 million tons by 1985 and 1,543 million tons by 1990. This will result in disturbance and mixing of the topsoil on approximately 14,000 acres by 1990. Disturbance will alter soil characteristics, micro-organisms and soil climate relationships which have been established over a long geologic time span. The current level of soil productivity will be lost for an indefinite period. Impact on topsoil increases in proportion to the increased mining rate. The topsoil disturbance per five-year period accelerates from 2,700 acres in the 1974 to 1980 period to 5,000 from 1980 to 1985 and 6,300 from 1985 to 1990. Some properties of topsoil will be destroyed by mining on 14,000 acres by 1990. This represents approximately 0.3 percent of the surface in the study area. Further mining would extend the impact beyond that level.

Mining involves removal of large volumes of overburden to reach coalbeds. Removal of overburden will result in complete alteration of soil horizons, parent material and soil characteristics. It could result in bringing to the surface elements, such as boron, which may be toxic to plant growth. At completion of mining operations, soil structure will be completely different from what it was prior to start of mining operations. Table 3 presents some idea of the volume which will be disturbed over the 14,000 acres mined for coal.

Table 3

Cumulative Volume of Overburden Disturbed

Year	Million Cubic Yards
1980	266.4
1985	772.2
1990	1388.7

In addition to the area of soil which will be disturbed by actual mining, soil disturbance will also result from construction of railroads, access roads, transmission lines, mine facilities, power plants, gasification plants, coal slurry pipeline, pipelines and new housing facilities. Much of this disturbance will result in permanent loss of productive soil surface. Soil surface disturbed and permanently removed by these activities is shown in Table 4. The impact of permanent soil surface loss is greatest in the 1974 to 1980 time period when 4,800 acres are lost to facility construction.

Table 4

Cumulative Soil Surface Acres Disturbed and Permanently Removed from Production

	Cause of Disturbance			
Year	Rights-of-Way	Facilities & Housing	Total	Permanently Removed
1980	3,100	3,100	6,200	4,800 (77%)
1985	6,000	6,100	12,100	7,900 (65%)
1990	7,500	7,500	15,000	9,500 (63%)

Without knowing the precise location of the disturbance on a yearly basis, it is difficult to determine which soil associations may be impacted. Since locations are known with a fair degree of accuracy for 1980, disturbed

acreage by soil associations were calculated. The data shown for the subsequent years is based on a simple proration formula. Table 5 includes acreages disturbed by all types of activities from 1980 to 1990. The table also includes acreage permanently removed which cannot be separated with the data available at this time (April 1974).

All of these disturbances will result in fine grained soil and parent material being exposed to wind and water actions. Soil productivity, permeability and infiltration rates will be reduced, increasing runoff, soil erosion and sedimentation. Wind action, which is almost constant over the entire area, will cause fine soil, silt and clay particles to be lifted into the atmosphere reducing air quality and adding to soil loss. Prior to revegetation of exposed soils, soil erosion resulting from high intensity storms will remove fine materials and can result in formation of gullies. Alteration of stream channels and increased velocity will accelerate erosion of stream banks and cause headcutting of the streams. This will add to soil loss and sedimentation.

Increased population within the study area (27,000 by 1980, 42,000 by 1985, and 47,000 by 1990) will cause other losses to soil values. Greater recreation use, originating from more population, will cause additional soil losses. Any increase in off-road vehicle use could cause serious impact on soils.

Even though land is reclaimed, soil will be lost and productivity reduced on 0.6 percent of the study area by 1990. As this loss will take place in probably the most productive area of the Eastern Powder River Coal Basin, the loss could be significant.

Table 5
Cumulative Soil Surface Acreage Disturbed by Association

Year	Soil Association Number* 1	3	7	8	9	10	11	13	14	19	20	Total
1980	213	3,319	214	698	240	144	1,821	247	295	210	1,499	8,900
1985	474	7,384	476	1,553	534	320	4,052	550	656	467	3,334	19,800
1990	690	10,815	697	2,274	782	469	5,933	805	961	684	4,886	29,000

*Refer to Chapter IV for description and name of each soil association.

Mineral Resources

The most important regional impact on minerals by the active and proposed mining and transportation operations is the impact on coal. Great tonnages of coal will be mined from the Eastern Powder River Coal Basin and used in the basin or exported. Most coal consumed as fuel within the basin is for the production of electric power or synthetic gas, much of which will be exported to consumers. Thus, the main impact is the removal and subsequent combustion of 1.5 billion tons of coal by 1990. This coal production will result in the depletion of a nonrenewable energy resource.

Some coal will be lost during mining, mostly by leaving fenders of coal to block spoil piles from working faces in areas where the mining situation dictates coal recovery is most efficient in narrow panels. This denial of coal can be temporary, and the subsequent impact minor because these fenders can be recovered before mining is completed.

An impact on coal could arise from the proposed location of the railroads. The proposed mainline will be located above coalbeds which are amenable to mining by surface and underground methods. The mainline right-of-way crosses an estimated 161 million tons of economically strippable coal. Should it become economically feasible to strip overburden to depths of 400 feet, then the proposed right-of-way would cross an additional 195 million tons of coal. The spur lines to be built into the mines will cross additional large amounts of strippable coal (Table 6).

Resources crossed by the railroad will not undergo impacts of loss but rather nonproduction to the extent that mining is not permitted.

Table 6

Coal Resources and Associated Overburden Along the Proposed Railroads and Spurlines

Overburden thickness Range in feet	Length of rail line in miles	Average thickness of coal in feet	Coal in millions of tons
	Proposed line		
0-200	18.5	40.5	160.8
200-400	13	70	195.1
over 400	15+		
	West alternate line		
0-200	4	48.5	41.6
200-400	15.5	56.4	187.6
over 400	25+		
	Mainline spur to North Rawhide mine		
0-200	0.5	50	5.4
200-400	0		
over 400	0		
Proposed line spur to Black Thunder and Jacobs Ranch mines*			
0-200	3.5	70	52.6
200-400	1	70	15.0
over 400	1		

*Add 2.0 miles of over 400 feet of overburden to these data for the spur to the alternate line.

Moving of spur lines to allow mining commonly takes place, so that the only impact of these lines on coal will be expense and time associated with having to relocate them prior to mining operations. Realignment of the mainline would be more expensive to accomplish and may not take place for decades.

The second major impact on minerals, resulting from mining of 1.5 billion tons of coal by 1990, will be from construction of facilities to support the coal mining and utilization. Significant utilization impacts will occur on aggregate materials. A plentiful supply of clinker is available from local sources near the burnline. Some sand and gravel is available from local streambeds. These materials will be consumed in foundations, structures, subgrades, road surfacing, and railroad ballast. Impacts will occur within and outside the study area. Aggregate will be imported from the Buffalo and Newcastle, Wyoming, areas and by rail from distant quarries.

The magnitude of this impact can best be illustrated by the following examples. Based on a silo height of 193.6 feet, an inside diameter of 70 feet, 1 foot thick walls, top slab 6 inches thick, and a base, the silo contains a total of 4,000 cubic yards of concrete and holds 12,000 tons of coal. Based on a typical design to obtain the necessary strength, approximately 3,600 cubic yards of sand and gravel would be required in construction of the silo. Assuming that one 193.6-foot tall silo is required per 1.5 million tons of coal mined per year, Table 7 shows the estimated sand and gravel needed for silos.

Table 7

Sand and Gravel Required for Silos

Year	Increase in Coal Production*	No. of Silos	Cumulative Cubic Yards of Sand & Gravel
1975	6	4	14,400
1980	83	55	198,000
1985	113	75	270,000
1990	145	97	349,200

*Increase based on 1973 base of 5 million tons, assumed that all coal is exported.

Therefore, for silos alone a total of 349,200 cubic yards of sand and gravel will be required by 1990. Additional material will be required for other numerous concrete structures to be built. The amount of surface which will be disturbed is undetermined. Only limited supplies of sand and gravel are found in the study area; therefore, most of this material will have to be imported. Most of the sand and gravel obtained in the area will come from streambeds within the study area impacting fish habitat and water quality.

Local clinker deposits will be utilized for subballast (roadbed) on the rail lines to be constructed. Assuming that 6,600 cubic yards will be required per mile of rail line, including road crossings, the cumulative amounts required will be: 1980 - 924,000 cubic yards, 1985 - 957,000 cubic yards and 1990 - 990,000 cubic yards, equivalent to about 61 acres of clinker about 10 feet thick. The impact on the total available clinker is negligible.

New roads will be constructed, each requiring use of aggregate material such as gravel, sand, and clinker. As state and county road construction will be involved, an estimate of aggregate needs is difficult to calculate,

but assuming that on an average 6,000 cubic yards are required per mile of road, the cumulative amounts required will be: 1980 - 96,000 cubic yards, 1985 - 120,000 cubic yards, and 1990 - 144,000 cubic yards, equivalent to nine acres of clinker 10 feet thick.

These few examples illustrate a cumulative need of 1.5 million cubic yards of material to be used by 1990 but represent only a small portion of the total demand that will have to be accommodated. The majority of the material will come from within the study area.

No known conflicts exist between actual or proposed mines and areas of oil and gas production. Most presently producing oil and gas wells in areas of proposed mines will be exhausted, plugged, and abandoned prior to mining. Oil and gas exploration and development can follow mining and reclamation without difficulty. Deferring oil and gas production until mining is completed may impact supply, but no loss would occur. The magnitude of this impact cannot be quantified at the regional level but it is not expected to be significant. Impacts with respect to well siting, flowlines, pipelines, treaters, separators, and tanks are mostly avoidable or easily and quickly negotiated. Railroad construction through producing areas is not expected to cause significant impact on oil and gas.

Uranium-bearing rock exists in overburden in some places and will be subject to impact from mining and construction projects. The major area of impact would be north of Douglas in the southern part of the study area. The Energy Resources map, No. 4 in Appendix A, shows locations where uranium and strippable coal deposits overlap. Uranium ores encountered or discovered during or prior to coal mining operations will be mined. Some uranium-bearing

material might be recovered that normally would not be mined because fragmentation and removal of overburden necessary to the mining of coal might enable economic uranium recovery.

Some minor amounts of uranium-bearing rock could be diluted during operations and construction and lost to further efforts of recovery. Some material may be covered by spoil or permanent structures and temporarily denied to examination and recovery. The magnitude of this impact is minor.

The cumulative impact on mineral resources through the year 1990 will be significant. By 1990 an estimated 12 percent of the presently economically strippable coal reserves will have been removed. The availability of sand and gravel material within the study area will be scare and commercially mineable deposits may be nonexistent.

Water Resources

Water supplies

Water is a resource that affects most facets of economic, social, and environmental conditions. Development of water supplies for northeastern Wyoming's coal and other energy resources could have a tremendous impact on all these facets. Because water can be transported from areas of supply to areas of demand, consideration must be given not only to water requirements of the Eastern Powder River Coal Basin but to those of the remainder of the Powder River Basin and to all possible sources of water, including imports from other basins.

Development of the Eastern Powder River coal deposits will have major but varying impacts on the water resources of the area depending upon how the coal will be utilized. Developing a water supply for the mining of 1.5 billion tons of coal by 1990, development of coal slurry pipelines, gasification plants, and power plants, and associated population increases within the area will have the larger impact. Exportation of coal only would have lesser impact on water utilization again depending upon mode of transportation, i.e., rail or slurry line. The estimated present and projected water uses are shown in Table 8. The assumption is made that all the water listed as requirements will eventually be consumed or disposed of as unuseable wastes. Figure 3 graphically portrays the potential for water development in the Powder River Basin and the cumulative water requirements expected to occur between 1974 and 1990. Figure 4 shows the expected increase in water requirements from 1974 to 1990.

The cumulative increase in water demands over present levels for the study area is approximately 28,000 acre-feet per year by 1980, 47,000 acre-feet per year by 1985, and 50,000 acre-feet per year by 1990. The water requirements for land reclamation have not been satisfactorily determined; this activity needs extensive research and experimentation.

Table 8

Estimated Present and Projected Water Requirements for Largest Users of Water in the Study Area and the Entire Powder River Structural Basin

Annual Water Requirements (acre-feet)

Type of Use	Study Area 1974	Study Area 1980	Study Area 1985	Study Area 1990	Structural Basin 1974	Structural Basin 1980	Structural Basin 1985	Structural Basin 1990
Irrigation	10,000	10,000	10,000	10,000	263,000	263,000	263,000	263,000
Reservoir Evaporation	30,000	30,000	30,000	30,000	85,000	85,000	90,000	90,000
Municipal**	8,000	15,400	18,600	20,000	21,000	29,000	32,000	36,000
Oil Field (water-flood)	12,000	12,000	12,000	12,000	17,000	17,000	16,000	16,000
Power Plants	8,430*	8,650*	14,150	19,650	9,000	50,000	75,000	100,000
Gasification Plants	0	7,000	14,000	14,000	0	25,000	32,000	44,000
Slurry Pipelines	0	15,000	15,000	15,000	0	15,000	30,000	45,000
Synthetic Liquid Fuel	0	0	0	0	0	7,000	42,000	60,000
Totals	68,430	98,050	113,750	120,650	395,000	491,000	580,000	654,000

*Includes Neil Simpson air-cooled and Dave Johnston water-cooled plants.
**Includes use outside of study area resulting from development in study area.

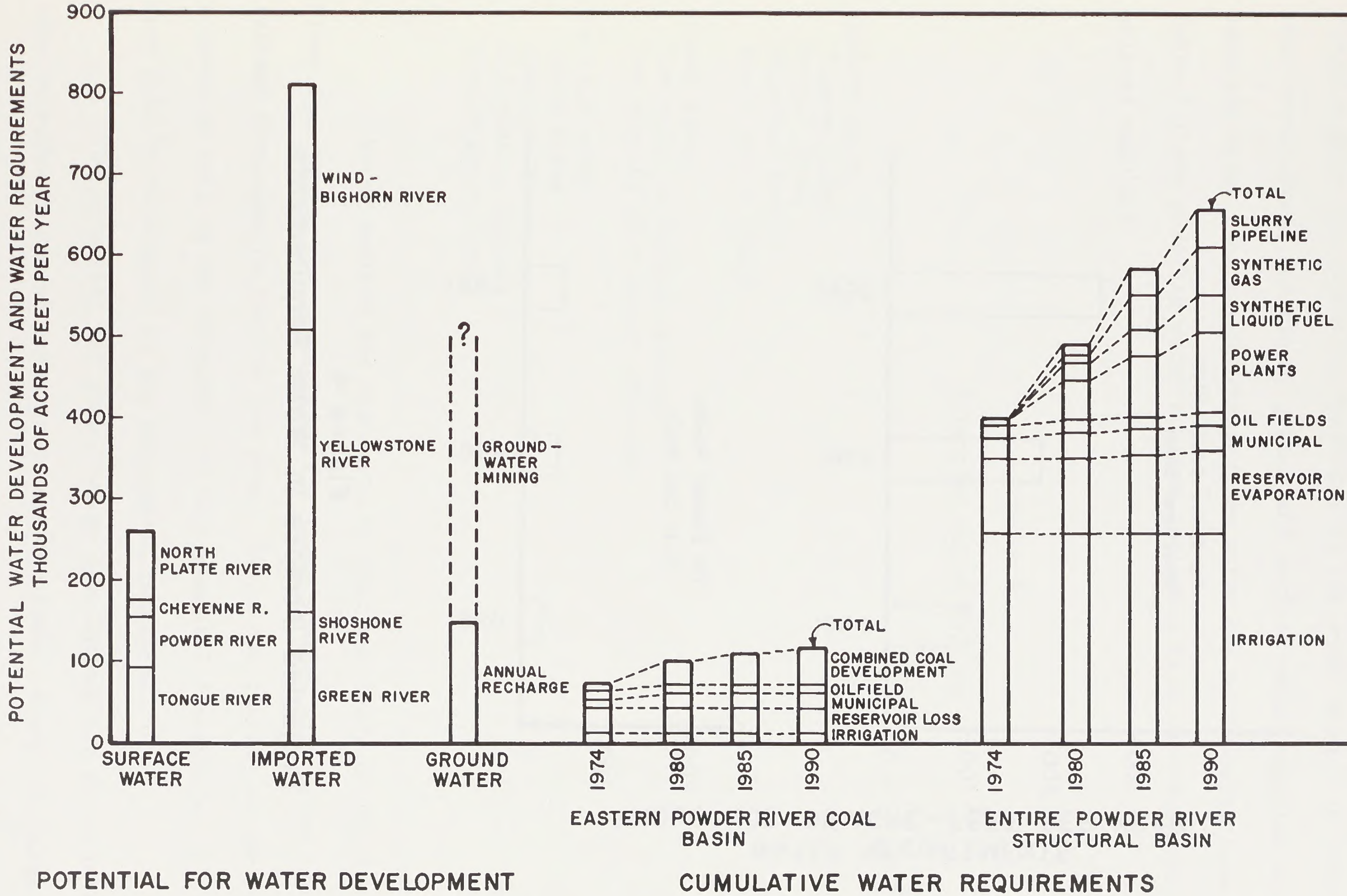


Figure 3
Potential Water Development and Water Requirements in the Powder River Basin, 1974 to 1990.

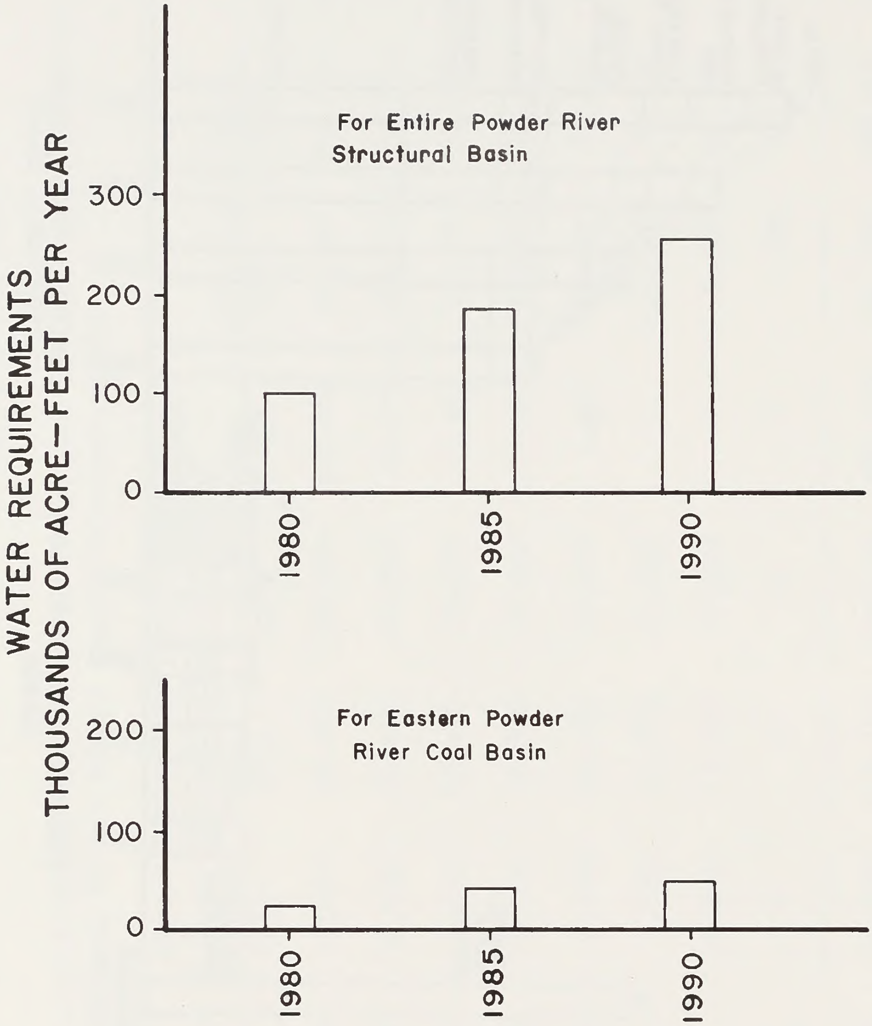


Figure 4
Projected Increase in Water Requirements

Planned coal developments require larger and more dependable water supplies than are presently developed in the study area. In order to fulfill this requirement, additional ground and surface water supplies may be developed, existing water uses may be changed, or water may be imported from other basins. Table 9 lists possible water sources available from current unused and unappropriated supplies.

Table 9

Potential Water Sources

	Acre-feet per year
Surface water	
Tongue River	96,400
Powder River	65,000
Cheyenne River	15,000
North Platte River	85,000
Ground water	
Use equal to annual recharge	150,000
Use greater than annual recharge	Unknown
Imported water	
Green River	120,000
Shoshone River	40,000
Yellowstone River	350,000
Wind/Bighorn Rivers	300,000

Water sources are available to meet the needs of the Eastern Powder River Coal Basin, but competition for these sources will occur from energy-related developments outside the area. Also, the quality of the various sources as well as the economic and environmental feasibility of their development must be considered by the individual companies.

The potential for ground water development for an infinitely long time is equal to annual recharge to the aquifers. Annual recharge (estimated

at 150,000 acre-feet per year) is more than enough to satisfy the total increase in demand for water (50,000 acre-feet per year by 1990) within the study area.

If desired, ground water development could greatly exceed 150,000 acre-feet per year by withdrawing ground water from storage in excess of annual recharge (mining of water). As described previously, several formations are capable of yielding 100 to 1,000 gpm of water to properly constructed wells. More than 3,000 gpm possibly could be obtained from individual wells that are open to all the aquifers from the top of the Fort Union formation to the base of the Madison Limestone in the study area. The depth to the base of the Madison ranges from about 8,000 feet in east central Campbell County to about 12,000 feet in southeastern Campbell County. With a spacing of one well in the center of each 40-acre tract (a distance of 1,320 feet between wells) and an assumed average yield of 2,000 gpm per well, each square mile would yield more than 52,000 acre-feet of water per year. This type of development in a little more than two square miles would supply the total requirements for the study area to 1990 (118,000 acre-feet per year) without depleting the ground water supply. In actual operations, the wells could be more widely dispersed, due to the dispersal of coal development activities, and the pumping lifts would be less.

Several companies, such as Energy Transportation Systems (coal slurry pipeline) and Panhandle Eastern Pipeline Co. (gasification plant), have indicated an interest in the use of ground water from the Madison Limestone. Other companies are exploring the shallower aquifers.

At this time, the proportion of water that will be obtained from ground water sources and from surface water sources has not been determined.

Each company is responsible for developing its own water supply, and each will be searching for and developing the most economical and dependable supply within the legal constraints of water rights.

Changes in the present surface water use of northeastern Wyoming could have significant effects on agriculture. Industrial companies have already purchased over 12,000 acres of irrigated lands with the intent of having the water rights changed from irrigation to industrial uses. Additional purchases are currently taking place as industries attempt to secure water supplies for their particular operations. Changes in the existing agricultural uses of this water would impact agriculture as well as wildlife populations.

Much of the water in the study area is not suitable for some uses, such as municipal, domestic, and boiler feed-water supplies, without desalting. Water quality requirements for other uses in the coal development industries have not been clearly specified. All the water in the study area probably would be acceptable for cooling and for use in slurry pipelines, but disposal of the residual cooling water presents serious problems. Dissolved solids are concentrated in the cooling water since part of the water is evaporated. Even though makeup water is introduced into the system, the concentration of dissolved solids in the cooling water eventually becomes so high all the water in the cooling system at that time must be discarded.

Possible alternatives for disposal of the cooling waste water are use for oil field flooding, evaporation from holding ponds, or injection into deep aquifers containing highly saline water. Use of evaporation ponds would still present a problem of solid waste disposal of the salt residue.

The salts could possibly be refined and marketed, but the market for such salts generally is poor. Otherwise, the salts would have to be transported to the ocean or other suitable site for disposal.

Disposal of sewage effluent from the increased population could present a similar problem. However, treated effluent probably will be used as a cooling water supply with the same disposal problems as described above.

Aquifers

Impacts during mining and reclamation

Mining will interrupt some alluvial and/or bedrock aquifers. By 1990, this disruption could occur on 14,000 acres or approximately three-tenths of one percent of the total study area. Backfilling will not restore the aquifer even though some of the fill becomes saturated. The best analogy to predict the water-bearing characteristic of the fill would be land-slide deposits, common in the northwestern part of the Powder River Basin. These deposits often have small springs and seeps at their base, but the deposits are too poorly sorted to be considered as sites for wells. Where the volume of overburden is small compared to the volume of coal removed, a depression will remain that may fill with water, forming a reservoir or lake.

During mining, water levels will be lowered in the vicinity of the mines. Water levels would also be lowered by pumping for incidental plant requirements or pumping of large quantities of ground water for either primary or supplemental supplies for steam generators, coal gasification plants, or slurry pipelines.

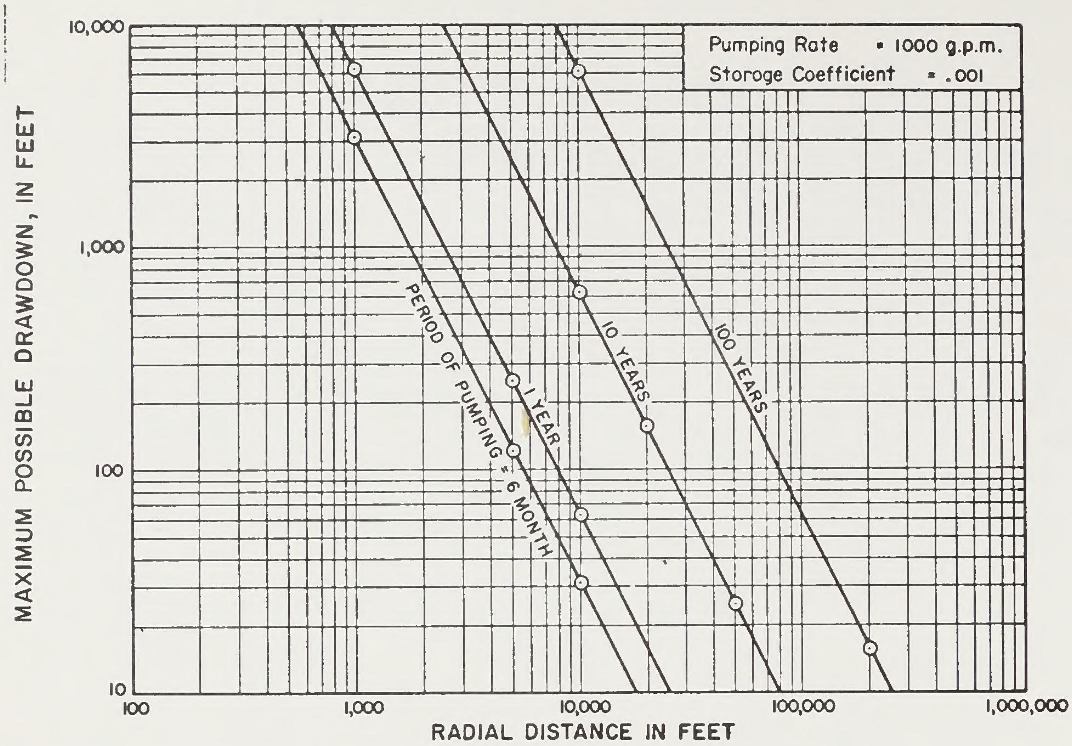
The areal extent of water level lowering will be dependent on aquifer geometry, aquifer properties, rate of pumping, and the length of time pumping occurs. The aquifer geometry may be the dominant factor determing the amount

that water levels are lowered when an aquifer is intersected by mining. Because of the presence of interbedded shale, water in many of the aquifers will be perched, and therefore, the base of the aquifer and not the bottom of the mine will be the discharge point to which the new water level gradient adjusts.

The effects of pumping from the Wasatch and Fort Union would differ, depending on rate and time of pumping, but otherwise would be analogous to the effects of pumping from the well field in the Town of Gillette. The water level in an observation well within a mile of the well field showed no decline that could be attributed to pumping of the field from the late 1940s to the late 1960s (Figure 20, Chapter IV). In the last two or three years, however, there has been a decline which can be related to increased pumping from the well field.

Effects of pumping from the Fox Hills Sandstone, Lance Formation, and the lower part of the Fort Union Formation in the vicinity of the mines where they occur at great depth, and from even deeper aquifers such as the Madison Limestone, will take many years to be transmitted to the outcrop areas and shallow domestic and stock wells. Figure 5 shows the maximum possible drawdown at different distances and different time periods. It was assumed that the coefficient of storage of the aquifers ranges between 0.0001, which is a reasonable estimate for a sandstone 100 feet thick, and 0.001 for a sandstone 1,000 feet thick, and that discharge is 1,000 gpm. Drawdown is directly proportional to discharge, so the drawdown at other pumping rates can be estimated from the graph.

In addition to lowering of water levels in wells, interruption and dewatering of aquifers could affect water levels in wells, discharge of springs and seeps, and flow of streams in the vicinity of mines.



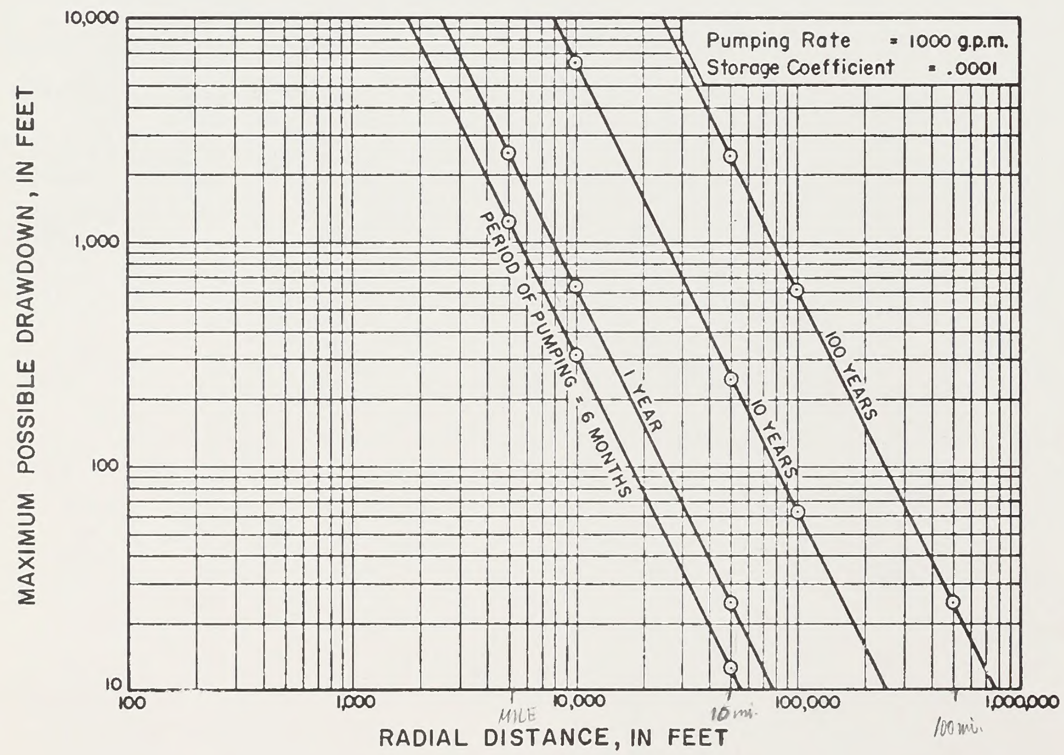


Figure 5

Maximum Possible Drawdown for a Given Distance and Time.

Coal mining near streams that were gaining water from ground water discharge during premining conditions would cause a reversal of ground water gradient. The gradient could be changed due to dewatering at the mine, and water could move toward the mine instead of toward the stream. If a good hydraulic connection exists between water in the stream and the underlying aquifer, downstream flow could be decreased because of mine dewatering. A reduction in streamflow could have a serious impact on aquatic life and vegetation dependent on that streamflow. However, there are no naturally perennial streams in the vicinity of the proposed mines. Another result of lower ground water levels would be the necessity of owners of wells to drill deeper to obtain water, which would be an economic impact.

Mine pits will be discharge points for all intercepted aquifers and there will be little opportunity for flow between aquifers until the area has been reclaimed. Some water could flow upward to the mine from deeper aquifers.

Mining operations will also alter the ground water recharge and discharge relationship. Edges of aquifers exposed in proposed mining areas are discharge points for ground water moving laterally. Mining would concentrate this discharge by changing the slope of the water table. In the event of flash floods, a mine could become partly filled with water, reversing the water table gradient, and the aquifer would be recharged for a time. However, subsequent dewatering of the mine to resume operation would again reverse the gradient so that the water which was recharged to the aquifer would be removed. The time required to remove the recharge from the aquifer would be of the same order of magnitude as the length of time recharge occurred.

Water pumped from storage in an aquifer is derived from three sources: 1) expansion of the water, 2) compression of the aquifer, and 3) compression

of adjacent and included clay beds. In areas of intensive ground water development where the artesian head is drawn down several hundred feet in aquifer systems with many clay interbeds, subsidence of the land surface can occur.

The shale that is interbedded with the sandstone and coal of the lower Tertiary and Upper Cretaceous aquifer system in the Powder River Basin will not yield nearly as much water by compression as might be expected of clay. Because the aquifer system is thick and shale constitutes nearly 50 percent of the formations, at least minor land subsidence must be considered as a possible effect of large withdrawals of water from the system.

Impacts after reclamation

After an area is reclaimed by partly or completely backfilling the mined area, there will be an opportunity for exchange of water between aquifers where the water level is sufficiently high and the area is not a discharge point. Flow between aquifers would locally decrease the head differences that occurred before mining, but the change would probably be insignificant when considering the total aquifer system.

Pre-existing recharge and discharge conditions in a mined area will not be restored by reclamation because of the disruption of aquifers. Where depressions remain below the water table, discharge will be greater than existed before mining, but where the depression remains above the water table, recharge will be enhanced.

The backfill may have higher porosity than the original material; however, permeability will be decreased because the backfill will be more heterogeneous than the original material. Where this material occurs in a discharge area, flow paths will diverge around the mined area or, possibly, some mounding and increased discharge will occur in the mined area. Where

local recharge occurred before mining, destruction of existing drainage patterns may, for a time, increase recharge by ponding water in the fill area. As drainage is reestablished, recharge will be less because of the lower permeability.

Surface flows

Impacts during mining and reclamation

Use of unappropriated surface water flows for coal development and associated uses would have varying environmental impacts. In order to assure a firm supply and to utilize the available surface water, construction of storage facilities would be necessary. Available surface water is limited in amount. Municipal and industrial water users will probably attempt to assure firm water supplies by buying or constructing storage capacity to meet their anticipated needs. Continued shortage will most likely be sustained by agricultural water users who cannot economically afford to provide the additional storage necessary to eliminate shortages in their supplies.

Construction of storage and diversion works will have increased impact on fisheries, recreation resources, agriculture land use, and aesthetics. Table 26, Chapter IV, lists applications for the larger reservoirs that have been filed with the Wyoming State Engineer. Many of the sites could provide greater storage capacity than indicated on the applications. Panhandle Eastern has already indicated that it has applied for purchase and change in use of North Platte River water. It also proposes to construct a 800-surface-acre, 24,000 acre-feet capacity reservoir on Soldier Creek near Douglas to supply water to its gasification plant.

Importation of water would affect the source area as well as northeastern Wyoming. Due to existing compact agreements and available supplies,

importation appears to be most likely from the Green River Basin. Development of this plan would have impacts in southwestern Wyoming where a reservoir would probably have to be constructed. Also, the quality of water in the lower Colorado River Basin is deteriorating and transbasin diversion of Green River water would cause further deterioration of quality.

Mining will also have direct impact on streamflow characteristics. The annual and low flows of the streams would be increased by the release of water pumped from the mines or by release of waste water from industrial plants. Peak flows would not be affected except in the small tributaries draining the developments. As open pit mines are most feasible where there is shallow overburden, the mines will generally be located within valleys, and the existing stream pattern of the site will be interrupted. Mining will cause alteration of various stream channels such as North Rawhide, Donkey, Little Thunder, and North Prong Creeks. These alterations could cause significant general and local effects on the geomorphology and hydraulics of the area's stream systems. Construction areas are highly susceptible to erosion. Introduction of large sediments into a stream may cause local aggradation which would steepen the channel and increase flow velocities, thereby causing instability of the stream at that site. Secondly, channelization may change the base level of the stream, and intervening tributaries will have to adjust to a new slope condition. As this adjustment takes place, head and downcutting of the tributaries could result in significant erosion of the watershed. Because headcutting of channels is a condition that moves upstream, the entire watershed of an intervening tributary can be affected by the alteration of a main channel.

Impacts after reclamation

Decreased permeability of the reclaimed overburden could result in lower infiltration rates, thus annual and low flows of the interrupted streams could be increased. Also, mined areas may be reclaimed so that a lake is formed, thus peak flows as well as annual runoff may be reduced.

Water quality

Impacts during mining and reclamation

Ground water. Water quality in aquifers will not be affected, except possibly very locally, by mining of coal because movement of water in the aquifers will be toward the mine, from which it will be pumped, rather than moving away from the mine area. Where water infiltrates to aquifers through backfill deposits, some leaching of common mineral constituents, and possibly some toxic trace elements, could occur. This water will not move far, however, and will be discharged into mines or along stream drainages or as transpiration by plants. Toxic levels of trace elements could be concentrated in plants and be consumed by livestock and wildlife. This possibility needs extensive research and monitoring. Acid waters from mining are not expected because the natural water of the area generally has a pH well above 7 and because of the small amounts of pyrite and other sulphide ores present in the coal.

Surface water. The amount of dissolved solids in streams below areas of development is expected to increase during mining and reclamation. Dissolved solids in water discharged from development areas will contribute to existing stream loads. Increased dissolved solids loads in streams can be expected from runoff from newly exposed surfaces.

Change in concentration of dissolved solids in the streams will depend on the amount and concentration of water discharged and its relation

to the amount and concentration of water in the streams at the time. Evaporative concentration of dissolved solids in the mixture of water will occur as it flows downstream. Greater effects will occur during periods when a larger portion of the water in the stream is received from development areas.

Precise changes in concentrations of dissolved solids in surface water cannot be predicted at present. Further studies, including applied research and monitoring, are needed.

Discharged waste water may include petroleum products, detergents, and solvents which, if allowed to discharge directly or indirectly to the stream through settling ponds or runoff, will decrease the quality of downstream water. Data is not available to assess the impact that sewage effluent would have on stream water quality in the coal basin if the effluent were released directly to streams. However, much of the sewage effluent is likely to be treated and used for industrial supplies before final disposal.

Sediment concentrations in streamflows may be increased by runoff from disturbed areas. Disturbed areas will include spoil piles, areas denuded by construction, and channelized stream courses. Due to the relatively small areas of the disturbances, change in sediment quantity will be mainly local.

Impacts after reclamation

Ground water. During the mining of coal, ground water will be moving toward the mining area, and thus no changes in the quality of the water in nearby aquifers can be expected. In the backfill areas, however, oxidation reduction zones will be disturbed and trace elements may be dissolved after mining stops, leaching of backfill deposits is possible, and a monitoring network of observation wells in the backfill area will be

necessary to detect changes in quality of water and movement of any leached constituents in the water.

After reclamation is completed, if waste materials from power and gasification plants have not been properly disposed of, contaminants from leaching of these wastes could affect the quality of water in some aquifers.

Surface water. Changes in surface water quality after reclamation is completed will be indicative of success in the reclamation effort. Surfaces left unprotected from erosion will continue to contribute dissolved solids to streamflow at higher than normal concentration. Sediment quantity will be dependent upon erosion.

Due to evaporation and the variability of precipitation, dissolved solids in pits that may be converted to reservoirs will increase in concentration.

Water rights

Coal development could change water uses and affect agriculture and wildlife. Industrial companies have already purchased over 12,000 acres of irrigated lands with the intent of having the attached water rights changed from irrigation to industrial uses. Changes in rights will mean that less water will be available for irrigation and agricultural use. Full utilization of unappropriated water will have impacts on other resource use such as recreation, fish and wildlife, etc. These secondary impacts are discussed in other sections of this statement.

Summary

Development of coal resources in the study area will create increased demand on water resources. Demand within the study area by 1990 will increase by 50,000 acre-feet per year over present uses (Table 8).

Demand in the Powder River Structural Basin, which includes an eight-county area, will increase by 259,000 acre-feet per year by 1990 (Table 8). The total of 259,000 acre-feet includes the 50,000 acre-feet increase in demand within the primary two-county study area. Demand for the additional 209,000 acre-feet of water by 1990 will be created by coal and other related energy developments occurring outside of the study area.

Permission to test deep aquifers to determine the feasibility of removal from Wyoming of up to 20,000 acre-feet of ground water per year from the Madison Limestone and overlying Bell Sand has been granted to Energy Transportation Inc. for use in its proposed coal slurry pipeline. Senate Enrolled Act #10 of the 42nd Legislature of the State of Wyoming granted this right, subject to approval by the State Engineer, provided the water was obtained 2,500 feet or more below the land surface. The application of Energy Transportation Inc. has not been approved by the State Engineer.

Increased industrial use of water may limit amounts available for agricultural and irrigation uses. This limitation or reduction could adversely impact other resource uses such as recreation, farming, wildlife, and grazing.

Overall water quality may decrease. The total effect on regional quality cannot be assessed with data currently available. Monitoring systems will be necessary to determine actual impacts on water quality.

Vegetation

Vegetation will be removed by mining operations, construction of plants and housing to accommodate the increased population, pipelines to transport coal and manufactured gas out of the study area and water to the plant facilities, rail lines to haul the coal, and transmission lines to transport electrical energy necessary to operate mines and plants and to move the developed energy to other areas. It will also be partially disturbed by increased recreational use originating from the larger population within and adjacent to the study area.

The impact on vegetation will start prior to actual mining operations. By 1980 an estimated 8,900 acres will have been disturbed. Approximately 54 percent of this vegetation (4,800 acres) will be permanently removed by construction of plant and mine facilities, particularly the gasification plant which requires an estimated 1,000 acres. Disturbance increases during the 1980 to 1985 time period as an additional 10,900 acres are disturbed with 28 percent (3,100 acres) permanently denuded. The impact lessens during the period between 1985 and 1990 when only 9,200 additional acres are denuded with 17 percent (1,600 acres) being permanently lost to vegetative growth. The total cumulative acreage disturbed by type is shown in Table 10. Since mining operations and locations are not known with any degree of certainty beyond 1980, an extrapolation was used to develop acreages by type beyond that date. Since location of mine operations is fairly well known up to 1980, the disturbance by type was calculated with a fair degree of accuracy.

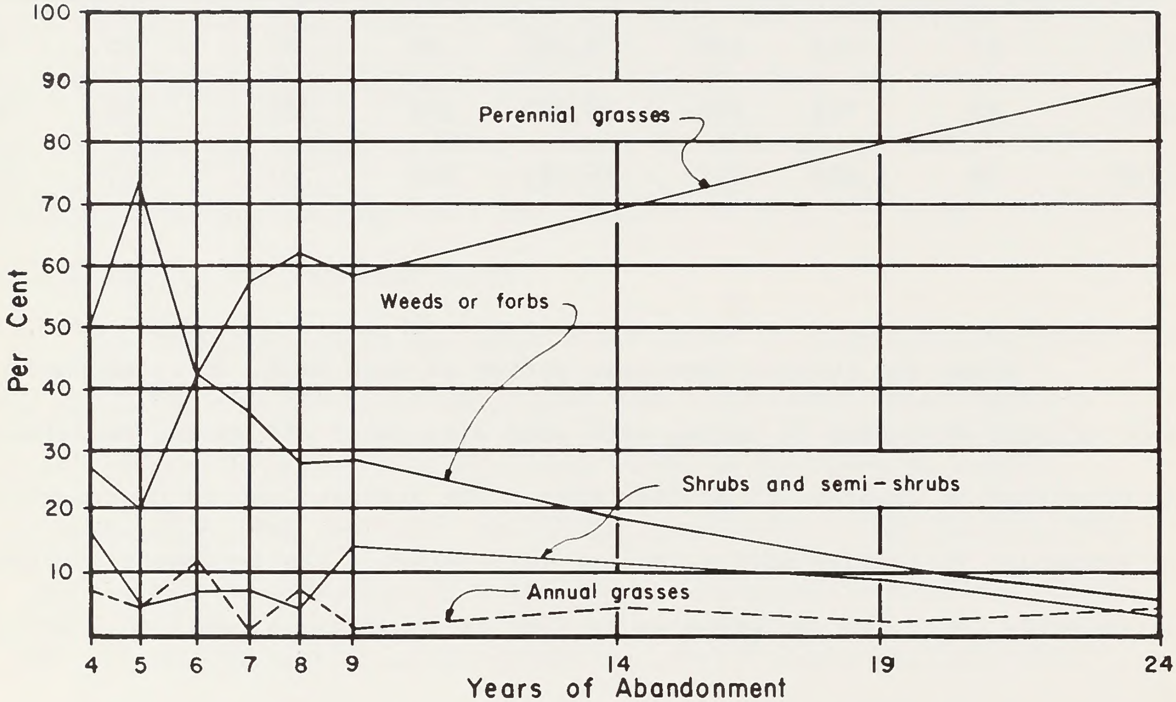
Table 10

Cumulative Disturbed Vegetative Type Acres

	Acres by Type							
Year	Dry Grass-land	Scoria Grass-land	Wet Meadow	Big Sage-brush	Grease-wood	Ponder-osa Pine	Broad-leaf Forest	Total
1980	24	315	128	8,211	80	82	42	8,90
1985	53	702	285	18,289	178	183	94	19,80
1990	78	1,026	417	26,751	260	267	137	29,00

After the initial five-year period at each mine, it is assumed that acreage disturbed by mining each year will equal the amount reclaimed as described in Chapter III of this Part. The acreage lost to construction of permanent facilities will be a long term impact. The acreage disturbed, permanently lost, and reclaimed up to 1990 is shown graphically in Chapter II.

Present plant succession will cease on all areas disturbed. Vegetation on disturbed acreage will be set back to a colonizing stage if reclamation procedures are not successful. Since mine areas represent severe disturbance and complete alteration of soil types, prediction of succession is sketchy at the utmost. The results of several studies of succession on abandoned farmlands in the sagebrush grasslands of the study area, lands which have not undergone the same type of upheavel as the mined area, will indicate that revegetation of disturbed lands to approximately original conditions can be expected to take over 50 years if left to natural succession (Lang 1941). Plant succession and percent of density on abandoned farmlands is shown graphically in Figure 6. The plant community after



Source: Lee Lang, "Some Vegetative Changes During Natural Succession on Abandoned Farm Land in Eastern Wyoming (Masters Thesis, University of Wyoming 1941), p.30.

Figure 6

Per Cent of the Total Density in the Vegetative Groups on Abandoned Farm Lands Subject to Natural Succession in Converse County, Wyoming in 1940.

reclamation may differ drastically from that present in the area now. The major component which will be missing in the reestablished community will be sagebrush.

Industrial fumes and dust from exposed coal, coal processing, roads, railroad hauling of coal, and loading operations will be deposited on vegetation adjacent to transportation routes and mining operations. This could effect plant vigor and may be damaging to leaves, especially when deposits are moistened by dew and light rain. Dust-covered and damaged vegetation may be less palatable and possibly toxic to livestock and wildlife Plant stack emissions, especially sulfur oxides, have a potentially damaging effect on ponderosa pine. Damage from this type of pollutant has been observed but not proven. Additional research is required to adequately determine the impact on vegetation from stack emissions resulting from coal-fired generating and gasification plants. This impact could damage extensive areas of vegetation beyond that physically disturbed by and as a result of coal development operations.

Changes in microclimate will occur depending upon the type of reclamation measures used. For example, changes in landform including change in slope and aspect will alter solar radiation intensities, airflow patterns, soil and air temperatures, snow accumulation, evapotranspiration, humidity, water bodies, and drainage patterns. Changes in surface color and ground texture will change soil temperatures. Change in vegetation type, for instance brush to grass, will change soil temperature, snow accumulation, air temperatures, soil moisture relationships, windflow, and shade. Changes in microclimate may have a detrimental effect on satisfactorily reestablishing vegetation following mining.

Archeological and Paleontological Values

Two archeological sites, Glenrock and Vore Buffalo Jumps, and two archeological-historical sites, Fort Phil Kearny and Fort Reno, listed on the National Register of Historic Places may be impacted by increased population brought on by coal and related developments. These sites will not receive any direct impacts from coal development.

Since there is a distinct lack of knowledge concerning archeological and paleontological values which may be located within the development area, analysis of impacts is difficult. There is reason to believe that these values do exist in the region to some degree, and the potential for significant impacts does exist.

Construction of all facilities discussed in the introduction of this section will require surface disturbance and earth movement. Estimated disturbed area will total 29,000 acres by 1990 within the region of economically strippable coal. Part of this acreage (9,500 acres) will be occupied by facilities thereby preventing assessment or examination of the overlain archeological and paleontological values.

In addition to impacts from surface disturbances, huge volumes of earth will be dug and moved during coal mining operations. An estimated 7.2 million cubic yards of material will be excavated for 1976 coal production of 8 million tons. About 1,543.9 million cubic yards of subsurface material will be excavated by 1990. Movement of this material will destroy archeological sites which may be buried within.

Increased population and the attendant increase of recreational use will also cause potential impacts on archeological sites which have not as yet been discovered or inventoried. Recreational use, particularly

off-road vehicle use, will create additional surface disturbances which would affect these values. Rockhounds, pot hunters, and arrowhead hunters could all cause an impact on potential archeological sites.

The most threatening impact, regionally, to archeological and paleontological resources is the permanent installation of facilities, displacement of data bearing soil, and the increased incidence of vandalism that will forever prevent identification and knowledge of prehistoric man and geologic history.

All the applicant companies have described their efforts to survey archeological values, some by contract with the State Archeologist, others through nonresident archeologists or local amateurs.

No known National Register sites or potentially eligible sites will be impacted by the direct action of coal and related facility development. However, because the potential for unknown values exists within soils of the study area, it is not possible to predict that no potentially eligible sites will be found. The overall regional impact of mining and its related surface disturbance of 29,000 acres by 1990 on archeological-paleontological values may appear insignificant in relation to the total size of the study area (4.9 million acres). However, the deep surface disturbance of 1,543.9 million cubic yards of potentially valuable (from an archeological viewpoint) material may be very significant. Because of this and the fact that potential archeological and paleontological values at this depth and near the level of the coal are unknown, impacts have the potential of being very significant.

Some positive impacts could accrue from coal development. A well supervised coal digging system could uncover valuable scientific data about life forms on the plains that might never be discovered otherwise because of the cost involved in exploring to these depths.

Historical Values

No significant sites have been identified within the area of presently economically strippable coal reserves or the proposed railroad route. The Sawyer Wagon Train Fight site (SE¼, sec. 12, T47N, R72W) and some abandoned homesteads on the Kerr-McGee mine property require further evaluation to determine their significance. These two sites are in areas of potential mining within the 1980 to 1990 time span. If these areas are mined, the sites will be destroyed.

Although no known significant sites exist in areas to be disturbed, major population increases (estimated 60,000 above current levels by 1990) are expected to occur within an eight-county area. This increase could have a secondary impact on all historic sites located within a half-day drive or less from major population centers of Gillette, Douglas, Casper, Buffalo, Sheridan, Newcastle, and Lusk. Increased population will place pressures on all the region's historic sites in the form of increased vandalism and pot hunting, especially at remote, unprotected sites. This impact will be modified in each instance, according to the sensitivity of the site, in terms of current physical conditions.

Much of the projected demand for sand and gravel, pipelines and right-of-way access roads may place added impact upon natural corridors occupied by potential national historic trails such as the Oregon, Mormon, and Bozeman Trails.

Impacts on historical values were developed in a study (Western Interpretive Services 1974) prepared specifically for this environmental impact statement. According to this study, the following sites will be susceptible to damage of vandalism and pot hunters:

Catonment Reno	Portuguese Houses
Fort Reno	Powder River Crossing
Hoe Ranch	Red Cloud Agency

A second possible negative impact is the road improvement required to meet demands of a larger, more dispersed population. The following sites

are located within close proximity to existing roads and are susceptible to physical impact resulting from road widening or realignment:

Antelope Springs	Seventeen Mile State Station
Minor Bozeman Trail Sites	Suggs
Crazy Woman Crossing	

A third potential negative impact will derive from community and industrial service facilities expansion. In order to meet increased water and power requirements, new pipelines and transmission lines will be routed into the area along natural corridors from Casper to Sheridan and from Douglas to Sheridan along the base of the Bighorn Mountains. A majority of historic sites identified in this study are located within proximity to these corridors and may be physically or visually impacted by pipeline or transmission line placement. High impact will occur within topographically restricted segments of the corridor.

A positive result of increased population is increased visitation at developed historic sites which will tend to foster greater appreciation of cultural and educational values as well as increasing the input of tourist dollars into local economy. The following sites are expected to enjoy greater visitation as a secondary impact of increased population:

Devils Tower	Fort Laramie
Fort Caspar Site Group	Oregon Trail Ruts
Fort Fetterman	Register Cliff
Fort Phil Kearny	

The remaining number of historic sites identified in the regional study area inventory are located at points remote from existing corridors or projected population centers and are not expected to be affected by increases in regional population or by coal development in the Eastern Powder River Coal Basin.

A professional historian (Bob Murray of Western Interpretive Services) has reviewed the list of existing and potentially eligible National Register sites with the Wyoming Historic Preservation Officer and determined that no impact will be made by the direct action of the proposed mines or railroad. Consultations and research will be continued to determine the importance of abandoned homesteads on the Kerr-McGee lease. Information on the historical surveys conducted by applicant companies and approving agencies have been forwarded to the National Advisory Council on Historic Preservation.

The overall effect of coal development may have a positive impact on historical values. This would result from the inventory and recognition of the private and public historical sites and the awareness that a potential impact exists from expansion of coal development and related activities.

Aesthetics

Coal development and its associated facilities will create impacts on the aesthetics of the study area and, to a lesser degree, areas outside study area boundaries. Development by 1990 of 11 new mines, four power plants and two gasification plants, mining of 1.5 billion tons of coal; increase in population of 60,000 in the Powder River Basin; and construction of 24 miles of road, 225 miles of powerline, 30 miles of coal slurry pipeline, and 150 miles of rail line will impact the elements (texture, lines, color, landforms, intrusions) which collectively make up the visual resource termed aesthetics.

Powerline, railroad, road, and pipeline construction and mining of coal will affect the texture of the study area. Texture mainly consists of a particular vegetative pattern. Fills and deep cuts created by the railroad and removal of vegetation over large areas or along a linear path create a new vegetative texture. A different texture is also created by reclamation of the areas disturbed by these activities. The area is reclaimed to a different type of vegetation with a height generally lower than the surrounding vegetative types. Then, too, some of the area may resist revegetation and remain barren, adding to the impact on texture.

Linear impacts are caused by rail lines, roads, powerlines, and canals and other water diversions. These facilities create unnatural lines on the landscape. In some cases, such as powerlines, the lines created are perpendicular to the natural lines of hills, cliffs, and rivers.

The predominant soft grays, greens, and browns of the present landscape will be impacted by use of red clinker for road surfacing material. Although red clinker hills exist in northern sections of Campbell County, the color of the rail line and ballast will contrast with the predominant color scheme of nature. All revegetated areas will contrast colorwise with surrounding vegetative

and land color. Species to be planted in reclaimed areas will be mostly grass, so the end result will be vast areas or long strips of colors contrasting with the surrounding mixture of grasses, shrubs, and brush. Powerline towers painted silver will provide a stark contrast with the soft greens and browns of present vegetation. Probably the most significant impact on the existing color scheme will be caused by construction and location of multi-hued buildings, homes and mobile homes throughout the region.

Cuts and fills necessary to construct roads and railroads change existing landforms. Maintaining a one percent grade on railroads will have a greater effect by requiring cuts and fills deeper than those required for roads. These cuts and fills alter landform in a linear fashion along a fairly narrow corridor, so the impact or the magnitude of the impact is restricted. Pipelines impact landform to a lesser degree, since they are buried. The major impact on landform is caused by mining and removal of large volumes of coal (1.5 billion tons by 1990). Mining results in lowering the altitude of the land, creating a more rounded and gently sloping landform and destroying abrupt changes in angles such as cliffs and sharp breaks. Impacts on landform are discussed in more detail under topography.

Every man-made or caused facility will be an intrusion and, therefore, an impact on the present landscape. Major intrusions will be those which protrude above the general plane of the landscape. Buildings, homes, plant facilities, loading silos, powerline support towers, and pumping stations will all alter the existing aesthetic character of the study area. Holding ponds and reservoirs, creating bodies of water where none existed before, are also intrusions but will not create significant impacts.

Elements which make up aesthetics have been discussed without regard to viewpoints. People view the landscape from many different points, on the ground and from the air. The view from each place along any traveled path is different. In an area this large (4.9 million acres) it is not possible to list or describe the various scene changes or the impacts on them, so impacts on viewing will be discussed in a broad fashion.

Scenic views will be changed. Indicators of this change will be unregulated solid waste disposal and litter near plants and communities, roadside billboards, bars, neon signs, and scattered tracts of new homes outside cities and around Keyhole Reservoir. Views of distant mountains and hills will be interrupted by industrial, residential, and service facilities. Because of new vertical intrusions on the skyline, many natural geologic formations will no longer be distant sights of interest. Silos at mines near these highways will capture the view. In most cases, power transmission lines and reduced air quality, especially during windy or inversions periods, will obscure the view of the Laramie Range from Interstate 25. Also, views of the Black Hills and Rochelle Hills will be modified. With new service facilities feeding Buffalo and Sheridan, some impacts will be felt upon major highways and views of the Bighorn Mountains.

The aesthetic quality of the area may be reduced for some. Others may enjoy the view of the changes more than the existing landscape. Aesthetic quality is a subjective blending together in one's mind of the various aesthetic elements. What can be said is that the cumulative impact of thousands of new people and development of all of the facilities associated with coal development will cause a change in the aesthetics of the Eastern Powder River Coal Basin.

The overall impact will be one of gradual change from what represents the quiet, rural setting, wide open spaces, basically uninhabited to a basin busy with industry and human activity. The quiet solitude and natural peacefulness will change as the area is developed. Signs of this change are already evident. The rate of change will quicken from now until 1980. During the 1980-1990 decade the rate of change will accelerate until peak development is reached and then remain fairly stable beyond 1990.

Wildlife and Fish

Coal development and industrialization of the Eastern Powder River Coal Basin will result in a significant impact on the fish and wildlife habitat and conversely on wildlife population quantity and quality. Development of 11 new mines, two gasification plants, four power plants and mining of a cumulative amount of 1.5 billion tons of coal by 1990 will physically destroy wildlife and its habitat, and reduce overall populations. The change of the area from a quiet, rural setting to one of bustling human activity, with population increases by 1990 of 47,000 within the study area and 13,000 adjacent to the study area, will indirectly affect wildlife and its habitat, resulting in a change in species composition and numbers that would be considered undesirable by many.

By 1990 it is estimated that 9,500 acres of habitat will be permanently destroyed, long-term productivity reduced on 19,500 acres and 116,000 acres impaired by increased human utilization. In addition, there will be an estimated annual loss of 200 deer and antelope in fences which will be constructed, reduction in base population of deer by five percent (850 deer), reduction of base population of antelope by nine percent (2,700 head), potential loss of the 300 head of elk currently inhabiting the study area, (particularly 90 elk in the Rochelle Hills), and an approximate loss of 940 to 1,250 sage grouse. These losses are the ones which can be quantified with any degree of accuracy. Undetermined losses of other animals will also occur.

There is a direct cause-effect relationship involved with impacts on fish and wildlife as a result of coal development. Direct mortality is rare on big game and other types which have the ability to flee. The direct action of coal development destroys or impairs habitat. This impact on habitat then translates itself into an impact on fish and animal residents,

resulting in loss. Therefore the impact analysis starts with examining the cause and the first effect--destruction of habitat and direct wildlife mortality. Then the analysis proceeds to translate this impact into its secondary effects, those on the animal itself.

<u>Habitat destruction and direct wildlife mortality</u>

A wide variety of development related actions will cause impacts on wildlife, and some of these such as loss of streams, ponds, lakes, springs, wells, and particular vegetative types, are not covered by quantitative impact projections made earlier in Chapter II. Where such projections and quantitative information concerning animal numbers, densities, or crucial habitat elements are unavailable, only qualitative analysis of impacts is possible. Each wildlife species in the study area will be subject to the cumulative effects of several of the different categories of impacts caused by coal development. These include:

--Direct destruction of animals.

--Permanent destruction of habitat.

--Initial destruction of habitat followed, in time, by some degree of recovery in habitat value.

--Impairment or reduction in value of habitat near human development or activities.

--Increased introduction of hazards into the wildlife environment.

--Offsite and secondary impacts caused by displaced animals, disrupted food chains, changed land and water uses, etc.

--Improvement of habitat.

A more detailed discussion of the probable impacts of coal development on the various animal communities of the study area and evidence supporting these conclusions is presented in Appendix C.

Direct destruction of animals

A number of development operations will directly destroy wild animals, ranging from individuals to entire populations. Those actions which cause the greatest losses are those which initially excavate, bury, overturn, clear, or grade large areas of previously undisturbed terrestrial habitat. The large machinery will bury, crush and suffocate many small animals, primarily those which are not capable of moving fast enough to escape and those which retreat to burrows for protection. Any operations, including well drilling, blasting or industrial and municipal use of water, which cause dewatering of aquatic habitats will result in death to fishes, aquatic invertebrates, and amphibians in certain stages of life. This type of destruction occurs over time. During the 1974 to 1980 time period surface disturbance which could result in direct mortality will occur over an estimated 8,900 acres. This impact will accelerate during the 1980 to 1985 time period when an additional estimated 10,900 acres will be disturbed. Since projected coal development levels off after 1985, the impact of surface disturbances covers only an additional 9,200 acres from 1985 to 1990.

Habitat losses

The variety of animals in the basin is too great to permit detailed description of development and rehabilitation impacts on each species. In Table 11, representative species are grouped according to important habitat requirements, habits, or life forms. Species in each group will be similarly affected by development action and rehabilitation. These species groups are used to illustrate differences in impacts due to differences in wildlife forms

and to illustrate trends in habitat values based on comparisions of existing habitat types with those expected to develop as a result of vegetative rehabilitation efforts.

Permanent habitat loss will result from actions such as construction of plants, distribution systems, communities, airports, etc. Greatest losses can be expected in the sagebrush and grassland vegetative types since they are predominant, but aquatic and terrestrial habitat will also be lost. Almost all animal species will be subjected to some permanent habitat losses. Total permanently lost acreage, based on projections, will approximate 4,800 acres by 1980, 7,900 acres by 1985, and 9,500 acres by 1990. The animals of Groups I, II, and III in Table 11 can be expected to suffer most. Where aquatic habitats are destroyed, animals in Group VIII will be impacted most severely.

Permanent habitat loss will be most significant during the 1980 to 1985 time period when an estimated loss of 3,100 acres, or 33 percent of the total estimated habitat to be lost by 1990, occurs.

By 1990, about 19,500 acres of wildlife habitat will have been disturbed which will have some, mostly long-term, potential for recovery. It is projected that about 11,800 acres of this will have undergone rehabilitation efforts aimed at establishing a perennial grassland vegetative type. Most of the habitat disturbed will be in the sagebrush and grassland vegetative types, but significant disturbance will also occur in aquatic, riparian, and pine-juniper habitats. After the initial loss, revegetation of disturbed areas by either man-induced or natural processes will begin to restore wildlife habitat in one form or another. Following initial attempts to rehabilitate disturbed areas to perennial grasslands, the majority

Table 11

Animal Species Representative of the Study Area, Listed According to Similarities in Habitat Requirements, Habits, or Life Form

Group I	In the study area, these animals are heavily dependant upon sagebrush for food or cover or nesting sites or combination thereof and/or other upland shrubs such as greasewood saltbush and rabbitbrush, especially for winter feed.	Pronghorn Antelope Mule Deer White-tailed Deer Sagebrush Vole Deer Mouse Least Chipmunk White-tailed Prairie Dog White-tailed Jack Rabbit Black-tailed Jack Rabbit Mountain Cottontail Desert Cottontail Sage Grouse Sharptail Grouse Sage Sparrow Dickcissel Lark Sparrow Brewer's Sparrow Sage Thrasher Lazuli Bunting Green-tailed Towhee Flycatcher,spp. Sagebrush Lizard
Group II	In the study area, these animals feed heavily on seeds and/or foliage or roots of weedy species of forb or annual grasses and/or meat on ground in open grasslands.	Thirteen-lined Ground Squirrel Richardson's Ground Squirrel Northern Pocket Gopher Wyoming Pocket Mouse Hispid Pocket Mouse Ord's Kangaroo Rat Western Harvest Mouse Plains Harvest Mouse Hungarian Partridge Mourning Dove Lark Bunting Savannah Sparrow Grasshopper Sparrow Vesper Sparrow Horned Lark
Group III	In the study area, these animals nest on the ground in open grasslands and/or feed primarily on perennial grass seeds or foliage.	Black-tailed Prairie Dog Prairie Vole Chestnut Collared Longspur McCown's Longspur
Group IV	In the study area, these animals depend primarily on the riparian (stream-side) plant associations and/or marshy or moist meadow areas around lakes or ponds to directly or indirectly provide food or cover or nesting or breeding sites or combinations thereof.	Raccoon Mink Striped Skunk Beaver Muskrat Long-tailed Vole Black-billed Magpie Red-shafted Flicker Wilson's Snipe Eastern Kingbird Traill's Flycatcher Goldfinch Catbird Long-billed Marsh Wren Brown Thrasher Robin Yellow Warbler Yellowthroat Long-tailed Chat Brown-headed Cowbird Western Hognose Snake Eastern Yellow-bellied Racer Common Garter Snake Plains Garter Snake Western Terrestrial Garter Snake
Group V	In the study area, these animals require the open pine timber, juniper breaks or rough, rocky topography for cover or food or nesting sites or a combination thereof.	Elk Bushytail Wood Rat Porcupine Pygmy Nuthatch Cassins Kingbird White-winged Junco Pinon Jay
Group VI	The composition of insect and spider populations and the relative abundance of different taxonomic groups vary with season, vegetative type and stage of succession. There is generally a greater variety of species and a greater abundance of individuals in the intermediate stages of grassland succession than in either the early or climax stages. Invertebrates are one of the three major groups of grazing animals.	Invertebrates, . . . including a wide variety of insect families and spiders such as: Springtails Long-horned Grasshoppers Short-horned Grasshoppers Barklice Thrips Plant Bugs Lace Bugs Seed Bugs Leafhoppers Aphids Ground Beetles Carrion Beetles Dermestid Beetles Darkling Beetles Snout Beetles Moths Midges Mosquitoes Wasps Ants Harvestmen Wolf Spiders Orb Weaver Spiders etc., etc.
Group VII	These animals are all highly insectivorous, if not totally so; their presence, density, and distribution is significantly influenced by the status of local insect populations.	Hoary Bat Big Brown Bat Little Brown Bat Vagrant Shrew Masked Shrew Grasshopper Mouse Common Nighthawk Western Kingbird Say's Phoebe Bank Swallow Rough-winged Swallow Eastern Bluebird Mountain Bluebird Loggerhead Shrike Bobolink Meadowlark Eastern Short-horned Lizard
Group VIII	Members of these animal groups found within the study area exhibit from high to total dependence upon stream, lake, or pond-marsh biotic communities for continued existence.	Waterfowl, Shorebirds, Amphibians, and Fish - Grebes Herons Geese Dabbling Ducks Diving Ducks Sandpipers Snipe Avocets Phalaropes Salamanders Frogs Toads Turtles Trouts Minnows Suckers Catfishes Sunfishes Perches
Group IX	These animals are somewhat wide-ranging and/or highly flexible predators. They prey, to varying extents, on members of most other groups. Their presence, abundance, and distribution are influenced primarily by availability of prey species; in some, it is strongly influenced by the availability of nesting trees, den sites, or burrows.	Coyote Red Fox Gray Fox Bobcat Long-tailed Weasel Black-footed Ferret Badger Great Horned Owl Burrowing Owl Long-eared Owl Short-eared Owl Cooper's Hawk Red-tailed Hawk Swainson's Hawk Rough-legged Hawk Ferruginous Hawk Bald Eagle Golden Eagle Marsh Hawk Prairie Falcon Sparrow Hawk Milksnake Bullsnake Prairie Rattlesnake

of the lands will most likely receive little or no special management consideration and will be subject to the same general conditions of climate, grazing, and land use as other rangelands in the region. Where artificial revegetation fails, natural plant succession will take over.

After analysis of the available data and considering failure-success reclamation probabilities, several general observations concerning the nature of the vegetative cover which will be established on disturbed lands between now and 1990 are:

--The total vegetative cover will be greatly reduced, probably near 50 percent of that found on adjacent undisturbed range.

--The shrub component will be absent or nearly so.

--There is a good possibility that reestablished plant communities will deteriorate rather than improve over time as they are exposed to periodic drought, continued grazing, etc.

--The composition trends of plant species groups will approximate those shown in Lang's graph (Figure 6). Exceptions will be, that where perennial grass establishment due to rehabilitation is fairly successful, the trend line will rise sharply in the first few years rather than later as shown and the weed or forb trend line will drop earlier.

Because of various important plant-animal interrelationships, the recovery of habitat value will approximate the recovery of the original plant community. Figure 7 presents a qualitative indication of trends in habitat value for several of the animal groups listed in Table 11. The species groupings, while flexible, are logical for the study area.

Amount of temporary disturbed habitat increases from 4,100 acres between 1974 to 1980, to 7,800 acres during the 1980 to 1985 period, and levels off to 7,600 acres between 1985 and 1990. Figure 7 can be utilized to project what the expected value of reclaimed acreage has for different wildlife species at time points beyond the initial disturbance. With the expected slow rate

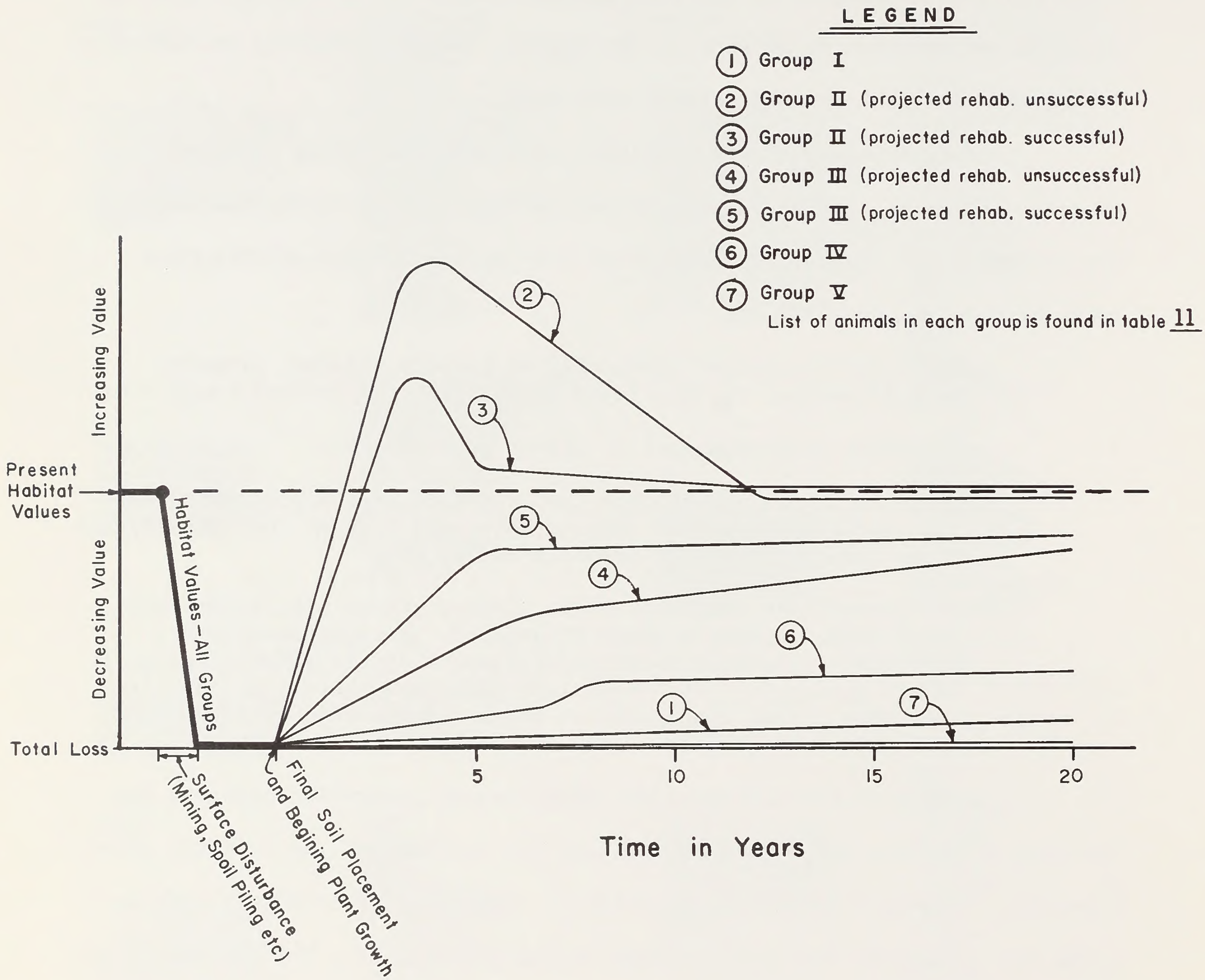


Figure 7

Expected Habitat Value Trends for Particular Animal Groups Following Attempts to Rehabilitate Severely Disturbed Lands to Perennial Grasslands.

of recovery, this habitat disturbance will most likely have a long-term cumulative impact on fish and wildlife populations and could result in losses which cannot be presently quantified.

Habitat impaired or reduced in value

The almost three-fold increase in population expected by 1990 will foster tremendous increases in human activity over the immediate study area. Humans will be living, working, and recreating in wildlife habitat never before subject to this level of intrusion. Human intrusion is tolerated only to a certain point by almost any wild animal. The degree of tolerance varies widely between species. As long as their habitat is intact, insects, for example, are relatively indifferent to human activity. Conversely, habitat of most of the larger mammals and predators will be abandoned close to areas of intense activity, i.e., around Gillette, Douglas, Buffalo, Sheridan, Newcastle, and National Grasslands. Habitat may be used only occasionally in areas near heavy, intermittent human concentration or use may be only lightly reduced with low-intensity human activity. It appears certain that the combined effects of impaired wildlife habitats will result in reduced wildlife production on an additional acreage three to five times larger than the projected 29,000 acres to be lost or reduced by 1990 through actual habitat destruction. Nearly all species will suffer, but those species of greatest interest to man, i.e., mule deer, antelope, sage grouse, will probably suffer most.

The major initial impact will occur in the 1974 to 1980 time period with population increases of 27,000 within the study area and 9,300 in adjacent areas. This impact will build from that point onward as population continues to expand and recreation use increases. The impact of this expanding population searching for recreational pursuits will significantly impair

habitat. Recreation use within the area is projected to increase from 1.4 million to 2.1 million visitor days by 1990. This use will increase the effect of coal development on fish and wildlife values.

Hazards introduced into the environment

Based on the 1970 rate of vehicle registrations per 1,000 persons, registered vehicles for Campbell and Converse Counties combined in 1990 may exceed 30,400 or a 43 percent increase over 1970. Such increased ground vehicle traffic throughout the study area will result in a proportionate increase in the level of road kills of deer, antelope, and numerous other animals.

By 1990, 150 miles of rail line are planned for construction in and near the study area. Collision hazards to various birds, small mammals, and big game species (deer and antelope) are certain to increase.

An estimated 500 to 1,000 miles of fence will be constructed around rehabilitated sites along highway, railroad, and secondary road rights-of-way and other areas. Several hundred additional deer and antelope can be expected to die in fences annually by 1990. Impacts will be compounded, especially during spring months, due to the attractive qualities of newly established grasses and forbs common on revegetated areas.

Increasing penetration, including off-road vehicle use, of presently remote or lightly traveled areas will take place. A tripled human population means that greater pressure upon coyote, bobcat, and fox populations will develop through predator calling, sport hunting, and trapping activities. Trapping takes many badger, raccoon, skunk, other mammals, and occasional birds as well. Indiscriminate shooting of animals and birds along and near roadways

will experience an upward trend even though certain species such as eagles and furbearers are protected or managed by federal and state laws.

Power demands will require construction of an estimated 225 miles of powerlines by 1990. Certain "in-flight" hazards to birds could occur. Powerlines represent an increase in the electrocution potential to large raptors.

Offsite and secondary impacts

Development of the study area will cause numerous secondary effects on wildlife through the disruption of food chains, behavior patterns, and various activities of species playing key roles in the ecosystem. Animals, especially big game, displaced from the 29,000 acres of disturbed habitat by 1990 and the much greater acreages of habitat "disturbed" by human activity will compete with resident animals for forage on adjacent ranges. While populations will ultimately be lost through natural mortality, there will be serious long-term reduction in carrying capacity of critical habitat in some areas. Predator-prey interaction will be disturbed, causing buildups of predators such as coyote in certain areas and switches in major prey species. Such disturbances can lead in time to increases in coyote predation on livestock and game species favored by man. Species such as the endangered black-footed ferret can be adversely affected by losses of prairie dog colonies. Prairie dog colonies are known within the area to be disturbed, but an inventory of all colonies is not available. Further adding to the problem of an inability to quantify possible impact on the black-footed ferret is the fact that a survey of the prairie dog towns to determine if they contain black-footed ferrets has not been accomplished. The only positive statement of impact that can be made is that reduction of prairie dog towns reduces

the ferret's food supply, and this in turn would reduce the possibility of ferrets maintaining themselves.

Impacts upon terrestial and aquatic habitat outside the study area must also be anticipated. Industrial water requirements in the Eastern Powder River Coal Basin may increase beyond that which is available "onsite." The proposal perhaps posing the most significant effects on habitat is that of transferring water use from agricultural lands to purely industrial uses. Much of this water maintains a fish and wildlife habitat base on irrigated meadows, irrigation ditches, streams, and reservoirs.

Concern for possible offsite long-term fish and wildlife reductions or changes through habitat impacts as the result of industry water use proposals cannot be overemphasized. The extent and types of faunal effects cannot be determined at this time. The prediction would depend upon presently unavailable information, including location and size of projects.

Improvement of habitat

The broad scale development forthcoming in the study area will mean some potential for improved habitat and benefited wildlife if we keep in mind that this usually means trade-offs.

The disturbance of large land areas is expected to result in vegetative changes favoring increases in population of some rodent species. Certain predators (coyotes, red fox, and various raptors) will benefit from these increases. These improved conditions are expected to be temporary on any particular area of disturbed land.

Specific group and species impacts

The impacts described previously add up to important cumulative adverse impacts on various fish and wildlife of the study area. Significantly, the magnitude mentioned does not totally quantify potential development of many private and state coal lands, coal development after 1990, or developments already expanding in the basin related to production of uranium, oil and gas, and others. The following attempts to summarize the total impacts from federal coal lease development on specific wildlife species and groups to the extent that information is available and impacts can be quantified.

Threatened species

Ten species (black-footed ferret, spotted bat, prairie falcon, American peregrine falcon, northern swift fox, ferrunginous hawk, prairie pigeon hawk, mountain plover, northern long-billed curlew, western burrowing owl) having threatened--including endangered--or undetermined population status are known or believed to occur in the Eastern Powder River Coal Basin. An additional four species (shovelnose sturgeon, goldeye and sturgeon chub, western smooth green snake) that have been identified by the Wyoming Game and Fish Department as being rare or endangered within the State of Wyoming may occur in the study area.

Inventories as to the exact occurrence and dependency of these species on the area to be developed and/or disturbed have not been accomplished. Therefore, precise impacts cannot be analyzed at this time. Habitat which is suitable for use of these species is found in the area. Unless certain species inhabit the area to be disturbed, where direct mortality could occur, the major impact would be a reduction of the range of habitat which is suitable for their continued existence. Without adequate knowledge of ranges and habitat requirements, any reduction in range may have serious long-term consequences.

Big game

Deer. Nearly 17,000 deer directly or indirectly depend on the study area for survival. Key deer habitat types, about 1,300,000 acres, occur in moderately timbered areas, rough breaks, and along drainage courses. Total deer habitat in the study area includes over 4,500,000 acres (Map 10, Appendix A). Deer, which are presently at or near maximum populations in balance with available habitat, will be displaced from parts of these areas and forced to compete with deer on adjacent lands. Deer numbers are determined by numerous factors which include the availability of food near suitable protective cover. The removal of existing browse plants through coal development activities will result in significant local reductions of deer.

No satisfactory evidence is presently available which would suggest that strip mined areas can be satisfactorily revegetated with plant communities that will satisfy the needs of deer. Therefore 50 percent of the total area disturbed by 1990 (14,500 acres) will be lost as deer habitat.

Human population growth and more intensive associated activities will further shrink the amount of favorable deer habitat. The combined effects of new human access to relatively undisturbed habitat, increased stress and competition for space (homes, service facilities), hazards (roads, increased hunting, fences, railroads), and other habitat loss may be expected to result in an estimated five percent reduction (or 850 deer) in the base deer population by 1990.

Antelope. Habitat (seasonal and year-long) is currently provided for about 30,300 antelope. Over 8,000 are harvested annually through sport hunting in and near the study area (Table 28 and Figure 63, Chapter IV). About 29,000 acres of antelope habitat, of which about 68 percent (19,700

acres) is winter range, will be physically lost from permanent disturbance and failure to properly rehabilitate by 1990.

Impacts described previously for deer mainly apply to pronghorns as well. Hazards such as fencing are particularly damaging to antelope, especially during periods of stress. In addition, successful reclamation efforts which result in simple grassland vegetation will not be sufficient for antelope.

Federal coal development in the study area will result in an estimated reduction in excess of nine percent (2,700 or more antelope) of the base antelope herd by 1990.

Elk. Coal development will deny elk a higher percentage of their habitat than other big game species. This is due to their greater inability to tolerate noise, activity, and human presence in areas of marginal cover. This fact alone will probably lead to the virtual disappearance of over 300 head of elk from the study area as population expands.

Fish

When mining or related operations involve the elimination or drastic modification of existing streams, ponds or reservoirs, direct habitat loss will result. It is not possible to project specifically how much "total" habitat loss will occur. Much of the fish habitat in the study area is already marginal due to intermittent, unpredictable, or very low flows and high water temperatures.

Annual and low flow of streams will sometimes be increased by the release of production water. Such "waste water" may include petroleum products, detergents, and solvents which, if allowed to discharge into streams, will decrease the quality of downstream water and interfere with or halt vital functions of fish populations.

The amount and concentration of dissolved solids in streams below areas of development will increase during mining and reclamation. This will result through runoff from disturbed areas such as spoil piles, denuded areas, and channelized stream courses. Both wind and water erosion will introduce sediment. Where resulting turbidity and siltation exceed tolerable levels, lowered biological productivity will result.

Water requirements for power plants and gasification and slurry pipelines will increase steadily through 1990. When large storage reservoirs are constructed, new fishery possibilities will be present if water quality is adequate. Stocking and other concerted management efforts may provide significant fish habitat at such sites.

Upland game birds

Sage grouse. Destruction and impairment of habitat, and in particular sagebrush grassland, will result in the loss of five to eight birds per square mile of habitat. An estimated three to four percent (940 to 1,250 birds) of the base sage grouse population in the study area will be lost due to coal development by 1990.

Sharp-tailed grouse. Good quality grassland and brushy cover requirements, coupled with nonmigratory behavioral tendencies, characterize this species. Habitat removal or severe disturbance will result in a direct and permanent loss of sharp-tails. Total population numbers are unknown so actual loss cannot be quantified.

Hungarian and chukar partridge. Populations are low in the study area. By further reducing available habitat, population declines will occur. Population inventories are unavailable. Therefore impact cannot be determined at this time.

Merriam's turkey. Turkeys represent a peripheral species in the study area. Their habitats of mountain forests and broken woodlands, characterized by ponderosa pine, fall generally outside of potential impact areas. Overall impacts to turkey populations are expected to be slight.

Mourning dove. The seed eating and migratory dove is highly adaptable to a wide variety of habitats. Insufficient information is presently available to fully analyze impacts upon the species. Preliminary investigations in the study area indicate the mourning dove to be a common species which seasonally depends heavily on grasslands and open ground for foraging. Dove experienced population increases in 1972 and 1974, declines between 1978 and 1970, reasonably static levels until 1972 and finally sharply increases by 1974. These preliminary results are based on three routes run in the general study area of northeastern Wyoming.

Waterfowl

The change or elimination of ponds, streams, and reservoirs will create an adverse impact upon waterfowl, especially ducks. Although dependent upon surface waters, the range of waterfowl extends beyond aquatic and riparian habitat located in the study area. Forced to move to other areas, waterfowl will be required to compete for suitable habitat. Where such resources are already utilized, overall waterfowl populations will be reduced. It is known that thousands of small reservoirs and permanent ponds in intermittent stream sections produce ducks. Brood production will be lost in those areas at an estimated rate of two to four ducks per surface acre of aquatic habitat disturbed or destroyed. Based only upon known aquatic habitat areas where losses appear likely, an estimated annual loss of 400 to 800 ducks can be expected. However, at the completion of mining, where overburden is not sufficient to completely reclaim the final pit, new water bodies may be created which would have a beneficial impact on waterfowl.

Other birds

All raptorial species, but particularly the eagles and peregrine and prairie falcons, are intolerant of human activity and habitat disturbance. Displacement of raptors will create territorial competition for adjacent habitat.

Human caused mortalities, such as shooting and collisions with autos, will increase.

Shore and song birds will be displaced and forced to seek new habitat areas. Since population levels are determined by the availability of suitable habitat, some will succumb to natural mortality.

Other mammals

Predators and furbearers. The availability and abundance of suitable prey species generally control the condition and level of predator populations. With destruction of insect, rodent, small mammal, and aquatic life, most predator populations will also suffer.

Predators such as coyotes, bobcats, and foxes will realize less immediate population impacts because of their wide ranging nature and flexible feeding habits. The badger has low ability to relocate and adapt to shrinking habitat conditions. Species such as the skunk and raccoon, closely tied to stream courses and riparian habitat, will experience population decline with habitat damage or removal.

Furbearers, including mink, beaver, and muskrat, will be extremely susceptible to habitat disturbance. The loss of aquatic habitat in association with riparian vegetation will drastically reduce, if not eliminate, these animals.

Rabbits and hares. This group consumes considerable amounts of grasses, shrubs, and other herbaceous material. Forced removal from home territories will result in intraspecific (among their own kind) competition. Using cottontail and jackrabbit densities indicated in limited studies, by 1990 cottontail and jackrabbit population of about 148 and 101 per square mile, respectively, will be lost on 28 square miles (estimated 7,000 rabbits)

and lost with only slight recovery on 19 more square miles which would involve approximately 4,700 rabbits.

Rodents, bats, and shrews. Substantial losses of small mammals will occur during mine operations in areas cleared for stripping, equipment work areas, etc. The existing fauna will likely succumb or move to adjacent areas where temporary, abnormally high densities might result. Mortality rates then would increase until population densities were again stabilized.

Rodents generally exhibit high reproductive rates which will likely allow rapid recolonization of successfully reclaimed lands.

Bats and shrews are largely insectivorous. Habitat removal will eliminate shrews while bats would possibly be able to effectively relocate themselves. The potential impacts to existing bat populations are not clear.

Invertebrates

Existing populations are diverse, numerous, and important for their positions in food chains. The majority of species present are herbivores. Permanent loss of vegetation through mining and construction of facilities will result in direct loss of invertebrates. The role of different invertebrates in a reclamation habitat may either be favorable as a result of insect-plant or insect-other-animal interactions, or undesirable as a result of one or more species becoming pests on vegetation in reclaimed areas.

Environmental damage followed by reclamation efforts will result in reduced invertebrate populations and changed species compositions. Population densities and diversities will be dependent upon the degree of reclamation success and the range of variation or tolerance ranges offered by "new habitat" produced.

Reptiles and amphibians

Available information is not sufficient to allow a complete analysis of impacts.

Species known or suspected to occur in the study area fall roughly into two categories--those which are intimately tied to surface water and those whose needs are chiefly terrestrial in nature. Most reptiles and amphibians do not readily migrate from disturbed areas. While the tolerance range of reptiles and amphibians is quite wide, elimination or drastic modification of surface water or terrestrial habitat will result in direct population losses.

Recreation

Major impacts on recreation use will result from loss of land base (8,900 acres by 1980, 19,800 acres by 1985, and 29,000 acres by 1990); increased population within the region (37,000 by 1980, 53,000 by 1985, and 60,000 by 1990; and change in water use and increased industrial and municipal consumption of water in the study area (27,600 acre-feet per year by 1980, 43,100 acre-feet per year by 1985, and 49,600 acre-feet per year by 1990). The impact will begin prior to opening of new mines and will become significant during the 1980 to 1985 interval, and level off thereafter.

The total area of Campbell and Converse Counties is approximately 5.7 million acres of which 700,000 acres are federal land and 460,000 acres are state land. Most of the federal and state land is in scattered tracts; however, the National Grasslands with 31,600 recreation visitor days in 1973 (344,000 acres) is the largest area of fairly well blocked federal land. The remaining federal land (385,000 acres) is scattered as small isolated tracts.

Therefore, any reduction in the recreation land base, although not significant when compared to total land base, may be extremely significant in comparison to the area available for this type of use.

The major recreation use in the study area today is hunting. Loss of approximately 29,000 acres of land by 1990 will reduce game populations (850 deer and 2,700 antelope). Hunting restrictions such as smaller hunt areas and shorter seasons will increase in order to provide maximum recreation opportunity yet maintain maximum producing big game herds. Because of population increase, resident hunting demand is expected to increase by 65,800 (66 percent) hunter days for antelope and deer over present levels by 1990. Projected increased resident hunting demands are shown in Table 12.

Table 12

Projected Increased Resident Hunting Demand

Animal	Hunter Days* 1980	1985	1990
Deer	22,500	32,800	37,000
Antelope	17,600	25,500	28,800
Total Increase	40,100	58,300	65,800

*Includes inside and adjacent to study area.

Industry with its attendant population increase will require additional acreage. Development of material sites, replacement agriculture lands, and increased recreational use, such as off-road vehicle use, will alter additional recreational land. As experienced in other states, when population and recreational use levels increase, more private land normally available for this type of use is closed and posted, further reducing the recreation land base. Residents have been very reluctant to pay hunting fees to landownders and rapid, rather significant, changes will have to take place in the attitudes of landowners and hunters if sufficient harvests are to be obtained. The loss resulting from this type of action could be more significant than the physical loss of land base to coal mining and its required permanent facilities. In all probability by 1985 the hunter will leave the study area to pursue his recreation in the adjacent mountains and plains. Hunting quality within the Eastern Powder River Coal Basin is not expected to return to its present level as commitment to development of the basin's coal energy mineral resources will have a long-term impact on wildlife populations and habitat.

Though limited in the basic study area, water-oriented recreation use does occur outside the region being analyzed. Coal development and associated activities will consume large amounts of water and decrease water quality. Wyoming statutes provide for a change of water right to higher, preferred uses, with industry use rated higher than agriculture. Agricultural water maintains a recreation base on irrigated meadows, ditches, fishing streams, and reservoirs which provide for an indeterminate amount of recreation use by fisherman, sightseer, hiker, and general outdoor user. If commitments of water involving the major mountain water courses are made to industry, these water losses will result in reduced water-based recreation opportunities and use. This water loss problem is clearly illustrated by Keyhole Reservoir which is presently being administered for recreation as a state park, yet approximately ninety percent of the water is sold to South Dakota. If this water were used, the state park would be destroyed and one of the major water-base recreation facilities in the study area would be lost.

Reduced water quality resulting from overutilization of sewage plants and solid waste from mine and conversion facilities (gasification and power plants), increased sedimentation as a result of accelerated erosion, and gravel mining in streams will affect fishing, swimming, and other associated recreational uses. This impact will be most noticeable offsite and downstream from the area of development along the Belle Fourche, Powder, and North Platte Rivers and reservoirs such as Keyhole and Glendo.

Much of the projected demand for sand, gravel, and clinker material (excess of 1.5 million cubic yards by 1990) may be mined from stream courses, alluvial mountain slopes, or limestone outcrops within the study area. This will impact scenic recreation lands, either directly (streambeds) or indirectly (sightseeing).

The anticipated population growth will generate increased demand on recreation facilities. Based on average per capita rates, the estimated

future recreation demand for such pursuits as hiking, picnicking, camping, etc., are shown in Table 13. Demand upon urban recreation facilities is illustrated in future projections as shown in Tables 35 and 35a, Appendix C.

Table 13

Recreation Visitor Days by Type

	1970	1990	Percent Increase
Hiking	167,649	275,565	64%
Picnicking	383,751	647,069	69%
Camping	253,809	424,789	67%
Fishing	503,663	646,632	28%
Boating	63,264	116,262	84%
Total	1,372,136	2,110,317	54%

Recreation facilities such as Little Thunder Reservoir and Little Powder River Wildlife Area in the National Grasslands and Devils Tower, Keyhole, Guernsey, and Glendo State Parks near the population centers of Gillette and Douglas (35-60 miles) will experience the greatest demand and be subjected to greater impacts.

With increased physical access, some additional federal land in the National Grasslands may become accessible for recreational use. This would offset some of the other losses in the recreation land base but also put additional pressure on wildlife needed for regional recreation.

Development of coal mines, power plants, gasification plants, railroads, and access roads will have a positive impact on recreational sightseeing. These facilities will provide interesting and educational viewing for the visitor, provided interpretive facilities are furnished.

Reduction in air quality from coal development and industrialization will impact the recreational sightseer. During inversion periods

and high winds, visibility will be reduced, obscuring the scenic views of the area and reducing the visitor's enjoyment. Additional powerlines will also impact the sightseer and reduce his enjoyment of the view.

Recreation quality is a subjective value judgment. The open, uncluttered, sparsely inhabited characteristics of the study area will change. To those who value solitude, this change will represent a loss. To those more gregarious, the change in type of recreational atmosphere will be a positive impact.

Selection of reservoir sites may have positive benefits for recreation (if reserves are dedicated); however, the sites may displace some of the few remaining stream fisheries. Rocky canyons and mountain meadows along streams provide excellent sources of food for fish and big game and if inundated will effect the remaining stream course below the dam.

The overall effect of coal mining on the recreation resource of the study area will be to diminish present quality for the residents. It may also affect long-term economic strength for certain business sectors by reducing nonresident recreation days. Increased use of recreation resources outside the study area could result in the lowering of recreation quality in an ever widening circle.

Agriculture

Development of Eastern Powder River Coal Basin coal reserves, on-site utilization and transportation within and out of the study area, will lead to changes in land use. These changes will ultimately be at the expense of existing agricultural lands since agriculture use is the dominant land use on approximately 94 percent (4,600,000 acres) of the study area.

Construction and development of the facilities described in the introductory part of this impact section will result in land use changes on approximately 29,000 acres. Of this amount, 33 percent (9,500 acres) will have been permanently removed from production by construction of plant facilities, residential areas, roads, and railroads. The remaining 19,500 acres will be in some sequence of reclamation. An estimated 61 percent (11,800 acres) of the temporarily disturbed area will have been reclaimed by 1990.

Approximately 0.6 percent of agricultural land will be disturbed and lost to production by 1990. The permanent loss will amount to only 0.2 percent of the total available agricultural land. The permanent loss is not a significant regional loss, but it may be quite significant to the rancher experiencing the loss. However, in most cases he is compensated through purchase of his land by the mining company.

Livestock grazing

It is anticipated that 35 percent of all coal development will take place in the vicinity of Gillette and northward, where a loss of 4.3 acres would represent the loss of one animal unit month of grazing (AUM). The major portion of the coal development is projected to take place between Gillette and Douglas in an area where each animal unit month of grazing is

assumed to average 6.5 acres. Based on these assumptions and an estimated 96 percent of the agricultural lands being used for livestock grazing, a summary of the projected annual loss of AUMs is shown in Table 14. At the assumed rate of development, the projected cumulative annual loss of livestock forage would be 1,515 AUMs by 1980, which increases to 3,435 AUMs by 1985 and 5,067 AUMs by 1990. Compared to an estimated total of 831,923 AUMs of average annual livestock forage available within the study area, this represents approximately 0.6 percent loss of the annual forage base by 1990.

Besides direct loss of livestock forage, secondary impacts associated with population increases due to construction, mining, and related developments will occur. Recreation use will occur that causes a nuisance problem and may cause temporary impairment of livestock forage use. Livestock are generally left unattended on the open range most of the time with little control other than fences. Improved access and the projected increase in population will result in increased vandalism of livestock watering facilities and fences by hunters and general outdoor recreationists. Rustling and disturbance of property has occurred in the past because of the inherent lack of protection. Molestation of grazing animals, especially during calving and lambing by off-road vehicle use, is a serious problem to ranchers. These types of incidents would be expected to increase. Expanding residential areas will result in greater impact on agricultural lands and grazing livestock.

Construction of railroads, highways, and service roads will lead to land separation and alter present ownership patterns. Railroad, highway, and many county or heavily travelled access roads are usually fenced to prevent accidents and loss of livestock. This will result in the separation and isolation of ranch properties, which will disrupt established use patterns, cause

Table 14

Summary of Projected Loss of Agricultural Land and Production

Year	Total Land Area Removed From Agricultural Production (Acres)	Land Removed From Livestock Forage Production (Acres)	Annual Livestock Forage Lost* (AUMs)			Land Removed From Crop Production (Acres)		Annual Hay Production Lost (Tons)			Annual Dryland Wheat Lost (Bushels)	Other Cropland Lost (Acres)	
			15"-17" Precip-itation Zone 4.3 Acres/AUM	10"-14" Precip-itation Zone 6.5 Acres/AUM	Total AUMs	Dryland	Irrigated**	Irrigated 1.62 Tons/Acre	Dryland .78 Tons/Acre	Total Tons	18.6 Bushels/Acre	Dryland	Irrigated
1980	8,900	8,352	680	835	1,515	189	359	439	77	516	1,265	21	89
1985	19,800	18,936	1,541	1,894	3,435	421	443	543	173	716	2,827	46	109
1990	29,000	27,934	2,274	2,793	5,067	616	450	549	254	803	4,129	68	111

*Assumes that 35 percent of the land disturbance will occur in the 15"-17" P.Z. and 65 percent in the 10"-14" P.Z.

**Acreage assumes most irrigation land will be lost in the Douglas vicinity mainly due to urbanization with a projected 50 acres loss per 1,000 increase in population.

access problems to livestock waters, buildings and for care of livestock. Small isolated tracts could result, which are too small in size to be used profitably.

Livestock drift with the wind during extreme blizzard conditions of severe winter storms. Historically, heavy livestock losses have occurred by animals being trapped by fences, deep-cut draws and other obstacles. Many projected developments will create additional obstacles. Additional livestock losses can be expected to occur from obstacles and traps created by additional fences, road and railroad rights-of-way and similar developments.

Physical separation of adjoining private land from Bureau of Land Management federal grazing leases and division of grazing allotments by fenced rights-of-way may cause loss of leases or, in the case of Forest Service administered lands, necessitate realignment of grazing allotment boundaries and users. Some loss of grazing use on federal lands will occur due to coal developmental activities and is included within the total projected loss of agricultural land and production.

Generally, each livestock watering facility services several square miles. Some loss of livestock water is anticipated through change of land use or land severance. Increased use of ground water supplies may also result in the loss of livestock water wells by lowering water levels. The loss of water source could affect the usability of several square miles of rangeland. The high cost of replacing wells and reservoirs may prevent easy reestablishment of adequate livestock water.

Some grazing lands could be affected by increased erosion and sedimentation. Alteration of drainages by mining or disturbed lands could cause accelerated erosion and headcutting in productive drainage bottoms resulting in additional losses of livestock forage. Sedimentation of livestock reservoirs would cause loss of water through reduction of storage capacities.

Farming

Loss of nonirrigated farmland production is estimated on the basis of total land area occupied, compared to the total county land area. A summary of the projected loss of crop production and farmland is contained in Table 14.

It is estimated that 189 acres of nonirrigated cropland would be removed from production by 1980, 421 acres by 1985, and 616 acres by 1990. Crop production losses by 1990 would, therefore, be anticipated to be equal to 254 tons of hay and 4,129 bushels of wheat annually. This would represent 0.7 percent of the estimated average annual nonirrigated hay production of 38,625 tons and 0.8 percent of the total nonirrigated wheat production of 528,652 bushels in the study area.

Impacts to irrigated croplands is anticipated to occur due to the projected expansion of Douglas. Additional irrigated cropland may be affected by industrial water diversions and rights-of-way for roads, pipelines, railroads, and similar developments.

The anticipated loss of 450 acres of irrigated cropland would result in a loss equal to 549 tons of hay, plus yield from 111 acres of miscellaneous and minor crops. This loss of hay production would represent approximately one percent of the 48,876 tons produced annually from irrigated croplands within the study area.

Loss of productive irrigated cropland will also occur from conversion of irrigation water rights to industrial use. The possible loss of irrigated cropland due to water conversion is shown in Table 15.

Table 15

Projected Cumulative Loss of Irrigated Cropland
Due to Water Right Conversion

	Projected Annual Industrial & Municipal (Acre/Feet)	Irrigated* Cropland Lost (Acres)
1980	12,620	11,473
1985	28,120	25,564
1990	34,620	31,473

*Assuming 1.1 acre-feet of water is used per acre of cropland.

Industry has already made known purchases of 12,000 acres of irrigated cropland with the intent of water right-conversion for use within the study area by 1980. This conversion would involve an estimated 13,200 acre-feet of water. Additional purchases are presently being made throughout the Powder River Basin and the North Platte River system in Wyoming for use in coal development inside and outside of the study area. Irrigation water is the major supply available to industry although some plans are being developed to obtain water from deep wells. The anticipated use of deep well water is not contained within the projected industrial and municipal water needs as shown in Table 15.

Based on present information, water is indicated to be in short supply to many acres of irrigated croplands. Loss of water for irrigation could not be readily replaced from existing sources. Approximately six percent of the irrigation water would be needed to satisfy the projected industrial and municipal needs by 1990. This represents the loss of a source of winter feed to the livestock industry equal to 67,200 tons of hay in an area with a winter feed deficit.

Summary

The direct loss of agricultural land and production by 1990 would not constitute an important regional impact as lost production by that time is anticipated to represent one percent or less of the total regional agricultural production.

Land severence problems, loss of livestock water, and other disruptions will occur and some livestock will be lost directly to hazards created by mining, construction, and operation activities. These impacts

will be localized in nature and would not involve a major change in the region's agriculture.

A projected six percent loss of irrigation water supplies and hence irrigated cropland production would not be considered to be a significant impact to overall agriculture within the study area. Locally, this could be a significant impact. However, water conversions beyond 1990 projections may have serious impacts on total irrigated cropland production within northeastern Wyoming and on livestock operations that rely on irrigated hay production for winter feed.

Impact on individual ranchers cannot be determined on a regional basis. Loss of agricultural land could result in higher prices within the area as additional supplies and livestock feed (hay) would have to be brought into the area.

Transportation Networks

Impact on transportation networks will be caused by: (1) mining of coal and construction of utilization and transportation facilities, (2) transportation of coal out of the study area, and (3) increased employment and population with its attendant increase in vehicles and miles travelled.

The actual impacts on transportation networks resulting from population increases will be primarily on highway commuting and airports. The Gillette/Campbell County Airport will most probably receive the major impact from increased use.

Based on the 1970 rate of vehicle registrations per 1,000 persons, the projected number of registered automobiles for Campbell and Converse Counties by 1990 is 30,400. This is 43 percent more than in 1970. The highway arteries that will be most impacted are State Highway 59 between Gillette and Douglas and U.S. Highways 14 and 16 combined, north and east of Gillette. By 1980, State Highway 59 is expected to have a flow of approximately 3,300 vehicles per day north of Reno Junction and 1,000 vehicles per day south. U.S. Highways 14 and 16 north of Gillette are expected to have about 2,400 vehicles per day. U.S. 14 and 16 east of Gillette will probably receive less traffic when Highway I-90 is completed. Increase in road maintenance and vehicle accidents will result. The Wyoming State Highway Department estimates that substantial improvement and upgrading of State Highway 59 between Gillette and Douglas will be required to accommodate the projected traffic flow increases. This upgrading and improvement will create minor environmental impacts on soils, vegetation, and wildlife. Present accident rate on this stretch is 2.6 per 100 million vehicle miles of travel. The State Highway Department predicts that even if traffic flow doubles or triples the rate will not change but more accidents will occur as the number of miles travelled will increase.

Carter Oil Company intends to reroute a portion of State Highway 59 north of Gillette to a point east of the coal lease. Overall impact is viewed as beneficial in that it takes through traffic further from the mining area to avoid possible congestion with mining traffic. This road is only lightly used with less than 400 vehicles per day. A limited number of minor graded dirt roads and gravel roads lie within mining lease areas but they are generally lightly travelled and could be rerouted if necessary without much disturbance to traffic. The State Highway Department foresees no difficulty with these roads.

Construction of the primary railroad route will cross as many as 50 unimproved and graded dirt roads and many lesser roads which are all generally lightly used for access to ranches and oil fields. Grade crossings or detours will be provided during construction which will cause an inconvenience impact on the traveller. Once the railroad commences transporting coal, 46 unit trains per day by 1990 may be expected from Gillette to Douglas. Impacts on the designated highways will be negligible inasmuch as they will be crossed by an overpass and thus not impede the flow of vehicular traffic. The Wyoming State Highway Department has indicated that a potential traffic tie-up problem may develop at Glendo where the existing railroad tracks cross U.S. Highway 26 and 87 combined. The present signal and gate at this location may have to be replaced by an overpass. Unlike the crossings of the designated highways, the crossings of numerous lesser roads will be by standard grade crossings. Although these roads are less travelled, train traffic of up to 46 trains per day will restrict freedom of travel across the tracks. A potential for an inestimable number of train-auto accidents is possible.

Numerous new roads, railroads, power and pipelines are proposed for construction. The pipelines and transmission lines are depicted on Figures 82

and 83, Chapter IV. These proposals, at least during the construction phase, will impact and disrupt some existing transportation networks. Minor electric transmission lines may require relocation due to mining activity but without inconvenience to the user or cost to the owner. A similar circumstance applies to any pipelines that may require relocations. Railroad construction is not expected to affect any electric transmission lines or pipelines other than requiring some minor line relocations. The construction of the three proposed 230-kv electric transmission lines is not expected to impact existing transportation networks. Highway crossings are usually achieved with a minimum of delay.

Construction of both the slurry and synthetic gas pipelines will cross numerous unimproved and graded dirt roads with little impact other than temporary detours during construction. Highways in this vicinity are not heavily travelled and little congestion or delay is expected. No impact is expected on electric transmission lines but other pipeline routes are being crossed and caution must be exercised during construction to avert the accidental rupture of an existing line.

A new highway is proposed for construction between Newcastle and Reno Junction which would give Newcastle a more direct link to the coal development area. Construction of this road is not expected to adversely affect any of the other transportation systems other than require an infrequent relocation of a pipeline or overhead transmission line.

Impact from the transportation of coal, its derivatives and service supplies is expected to manifest itself on highways and railroads only. The actual transportation of electricity by powerlines, coal by slurry pipeline, synthetic gas by pipeline, and water by aquaduct will not impact other systems.

The shipment of service supplies by highway will increase traffic between Newcastle and Reno Junction and between Casper and the two Cities of Gillette and Douglas. Increased traffic will induce incremental road wear and higher maintenance costs. The highway between Casper and Douglas is of high standard and appears able to withstand the increase in traffic without modification, but the route between Midwest and Reno Junction will require considerable upgrading to accommodate service supplies traffic (see Figure 80, Chapter IV, for location).

The existing railroad line was built a number of years ago to a standard that did not contemplate the shipment of a large number of heavy trains hauling coal on a daily basis. This line will thus experience rapid deterioration from its present condition and will require significantly large amounts of capital to maintain it at a standard high enough to keep accident probability low. Burlington Northern is planning and programming for the upgrading of all lines which will experience coal train traffic. Upgrading is usually accomplished by replacing deterioriated ties and laying a heavier grade of rail. Where the main line crosses highways or roads, minor delays may be caused by this upgrading.

Land Tenure

The impending development of the Eastern Powder River Coal Basin has already impacted land tenure. The recent trend of change in ownership from individual to corporate ownership is apparently in anticipation of issuance of additional federal coal leases and pending approval of mining plans on existing coal leases. Many companies are acquiring land in the name of the company, a subsidiary ranching operation, or a subsidiary mining operation. The general impact of change in ownership is to reinforce the general trend of deemphasis of agricultural and grazing land use with the possible outcome that once these lands are corporately owned, they may be held as investment properties and perhaps permanently removed from their original agricultural use. Present ranchers will have to buy comparable property elsewhere, get by with less acreage in their operation, arrange a lease and repurchase agreement, or get out of the ranching business entirely.

Conversations with the county assessor's offices in Campbell and Converse Counties and with numerous other sources provide only a wide range for the number of private acres that have passed into corporate ownership. These sources estimate that over the last five years 30,000 to 50,000 acres in each county have passed from private to corporate ownership. Many companies are still in the negotiation stage of their land purchases, and an accurate estimate of total acreage involved is unavailable.

Socio-Economic Conditions

The general approach and methodology utilized in analyses of impacts on the socio-economic baseline conditions of the study area is contained in Appendix C.

Development of the coal resources of Campbell and Converse Counties with associated increases in employment and population will have varying impacts on the socio-economic conditions of the basic study area and surrounding areas. In fact, the increase in population which will occur is the foundation and cause of many of the secondary impacts associated with coal development.

Population

Population projections for the cities and counties of the Eastern Powder River Coal Basin from 1980 to 1990 are only estimates of conditions considered likely to occur, not predictions. The model from which the population estimates were developed is located in Appendix C.

Projected population distribution

In the eight-county region (Campbell, Converse, Crook, Johnson, Natrona, Niobrara, Sheridan, and Weston) population has been projected to increase from 107,364 in 1970 to approximately 167,000 in 1990 as a consequence of forthcoming coal and other industrial development (Table 16). During this 20-year period, population will have expanded in the eight-county region approximately 55 percent. The most populous county will continue to be Natrona with an anticipated 1990 population of 61,800 which represents an increase of 20.6 percent relative to the 1970 population of 51,264. Campbell County will experience the greatest percentage increase of any county in the region during the period 1970 to 1990 (Figure 8).

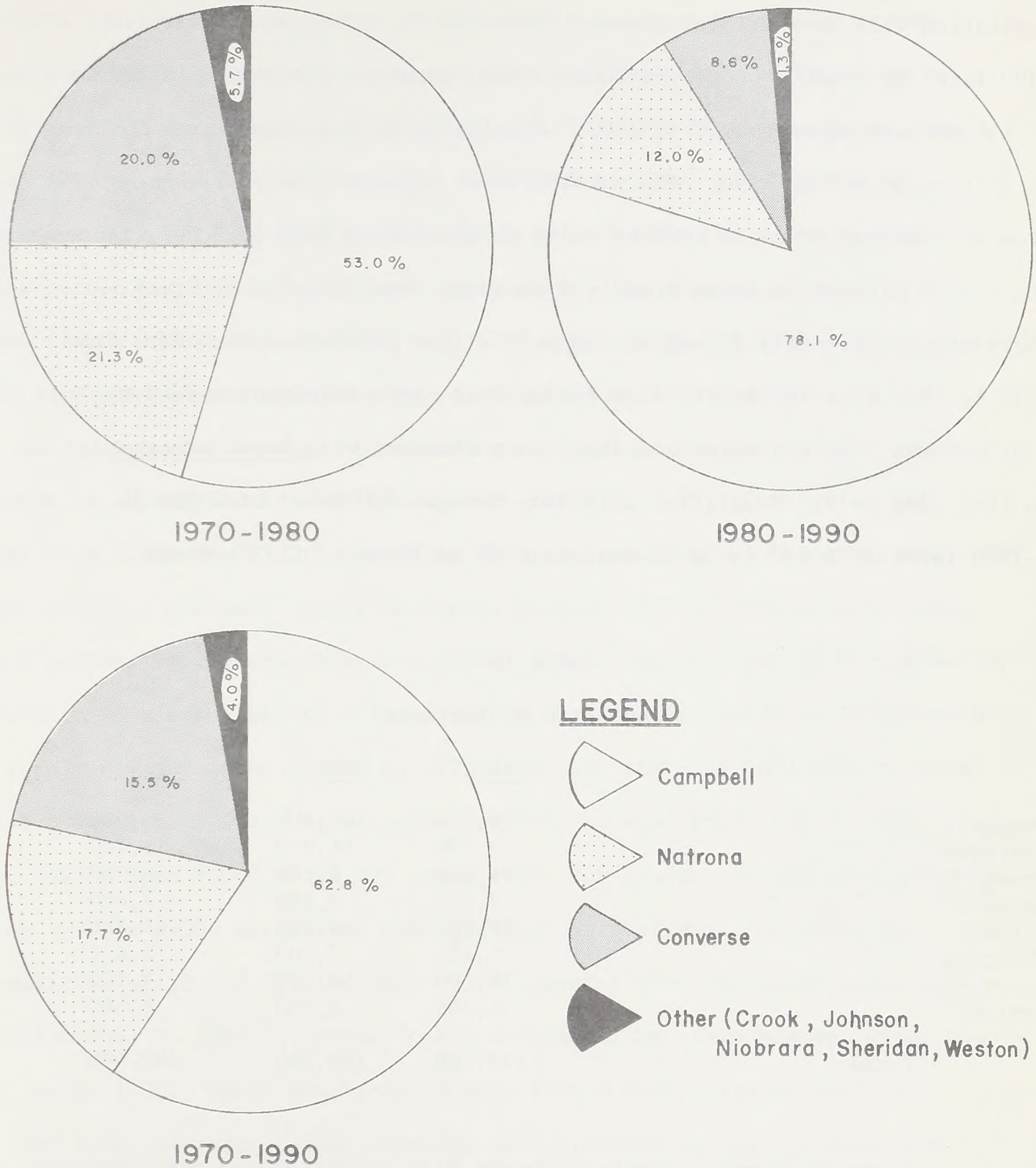


Figure 8
County Growth as a Percent of Regional Growth

Population will have tripled from a 1970 total of 12,597 to a projected 1990 level of 50,400. Converse County will encounter population expansion of 156 percent between 1970 to 1990. Population will increase from 5,938 in 1970 to 15,200 in 1990. The population of Johnson County will grow from an existing level in 1970 of 5,587 to a total in 1990 of 7,400, representing a 32.5 percent increase from 1970 to 1990. The Counties of Crook, Sheridan, and Weston will experience only slight population increases from 1970 to 1990 with the growth rate during that time period not exceeding four percent. Of the eight counties, only Niobrara will have less population in 1990 than 1970. Population will drop from a 1970 level of 2,924 to a 1990 level of 2,600 for a 20-year rate of decrease of 11.1 percent.

Table 16

Population Projections

	1980	1985	1990
Campbell	32,200	46,600	50,400
Converse	13,200	14,900	15,200
Crook	4,500	4,600	4,600
Johnson	7,500	7,400	7,400
Natrona	59,000	60,400	61,800
Niobrara	2,800	2,700	2,600
Sheridan	18,200	18,300	18,500
Weston	6,300	6,300	6,500
Total	143,700	160,200	167,000

Campbell County. Campbell County will be the second most populous county in the Eastern Powder River Coal Basin with an anticipated 1990 population of 50,400, 300 percent higher than the current 1970 population of 12,597. Campbell County between 1970 to 1990 will capture over 60 percent of the anticipated regional population increase of approximately 63,000

(Figure 9). Population growth will be most pronounced from 1975 to 1980 when population will nearly double. Growth will continue to rise from 1980 to 1985, increasing from 32,200 to 45,600. The five-year growth rate from 1980 to 1985 is 41.6 percent. From 1985 to 1990, population will increase at a rate of 10.5 percent which is less than the previous five-year period but still the highest regionally. The City of Gillette will grow from a 1970 total of 7,194 to a 1990 total of 28,000 (Table 44, Appendix C). The projected 20-year growth rate for Gillette is 289.2 percent.

Converse County. Converse County will be the fourth most populous county in the region by 1990 having been fifth in 1970. Population will rise from 5,938 in 1970 to 15,200 in 1990, representing a 20-year growth rate of 156.6 percent. Converse County between 1970 to 1990 will capture 15.5 percent of the anticipated regional population increase of approximately 63,000. Population growth will be most pronounced from 1970 to 1975, reaching a total of 9,900. Population in 1975 will have risen by 66.7 percent from a 1970 level of 5,938. Growth will continue to rise from 1975 to 1980, increasing from 9,900 to 13,200 for a five-year growth rate of 33.3 percent. From 1980 to 1990, population will grow but more slowly. In 1990, the population of 15,200 will be about 2,000 greater than the anticipated 1980 population. In 1990, Converse County will have two urban places[1] as opposed to one in 1970. While Douglas will grow from a 1970 total of 2,677 to a 1990 total of about 7,000, Glenrock will increase during the same time period from 1,515 to nearly 4,000 (Table 44, Appendix C).

Crook, Johnson, Natrona, Niobrara, Sheridan and Weston Counties. Population growth from 1970 to 1990 will be most prominent in Johnson and

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[1]Urban place is defined as a city with a population greater than 2,500.

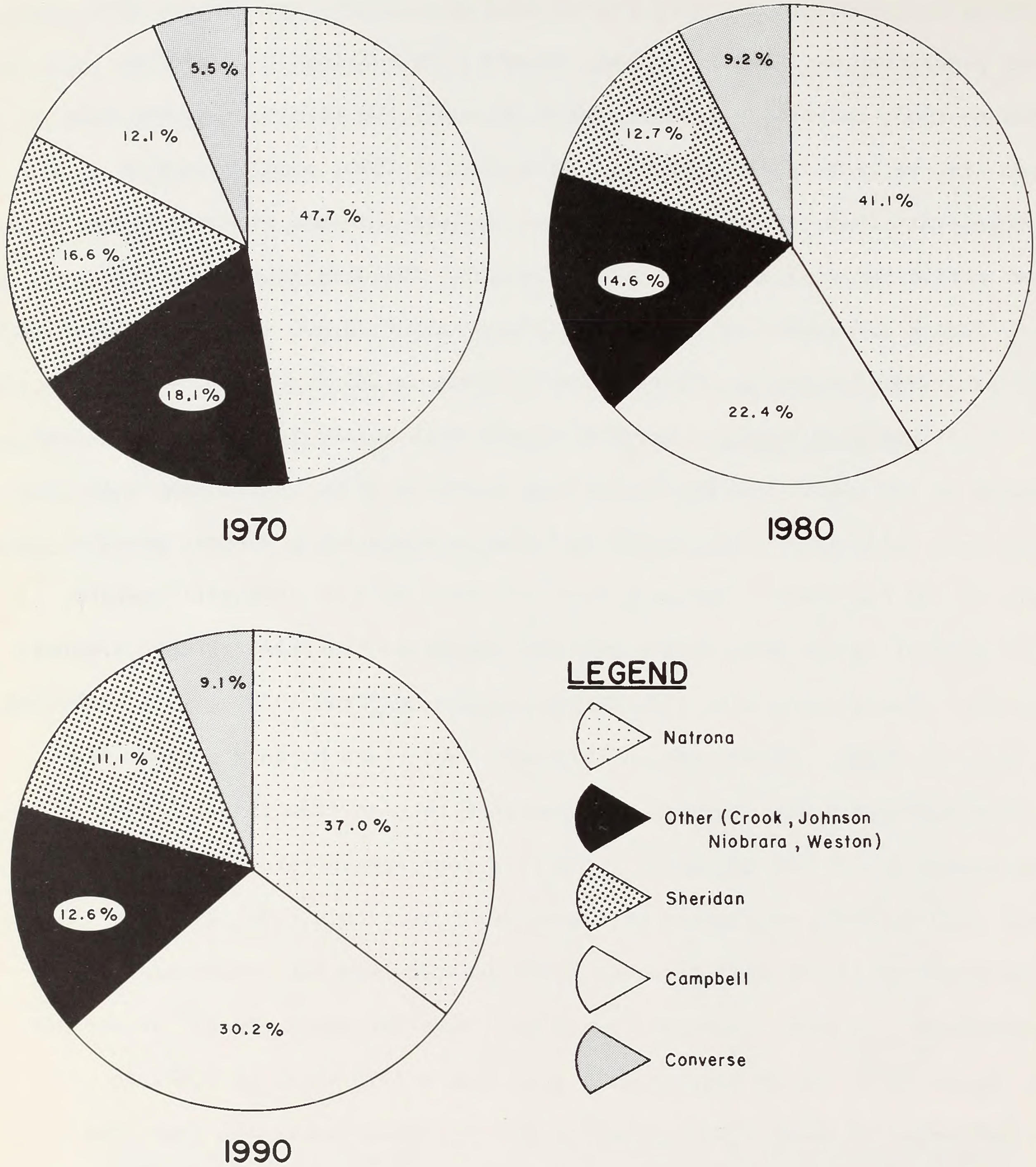

Figure 9

Population Distribution, Powder River Basin, Wyoming, 1970, 1980, 1990

Natrona Counties. During this time period, population in Johnson County will increase by 32.5 percent from 5,587 to 7,400; population in Natrona County will grow by 20.6 percent from 51,264 to 61,800. Population in Crook, Sheridan, and Weston Counties will experience no more than four percent growth from 1970 to 1990. Only Niobrara will lose population. Population in Niobrara County will be 2,600 in 1990 which is a decline in 20 years of 11.1 percent. This six-county subregion will capture about 25 percent of the anticipated 1990 regional population increase of approximately 60,000. Natrona County will receive approximately 10,500 or nearly two-thirds of the 1990 subregional growth with the Counties of Crook, Johnson, Sheridan, and Weston sharing in the other one-third. Population growth between 1970 and 1990 for the Counties of Crook, Sheridan, and Weston will be stable and inconsequential except for Niobrara which will consistently lose population. The City of Casper will remain the largest city in the study area. The population of Casper will grow between 1970 and 1990 from 39,361 to about 47,000. Of the other urban places in the six-county subregion, only the City of Buffalo will experience significant population growth. Buffalo will grow from 3,394 in 1970 to approximately 4,500 in 1990 which is a 20-year growth rate of 32.6 percent. The Cities of Newcastle and Sheridan will encounter very little growth, i.e., less than four percent from 1970 to 1990.

Urban growth centers. There will exist two major population centers in the Eastern Powder River Coal Basin by 1990 compared to a single center in 1970. Prior to coal and other industrial development, Casper in Natrona County was the principal urban center. Currently, Sheridan is the second most populous city in the Powder River Basin and serves as a focus for county activities. Energy development and construction of a railroad line from

Gillette to Douglas will alter the population balance. By 1990 population in the City of Gillette will reach 28,000, while population in the City of Casper will be 47,000. Gillette rather than Sheridan will become the second most populous city. Although Casper historically has been the major urban center because of its relative greater size, Gillette with its increased population may begin to attract certain economic activities which otherwise would have preferred to locate in Casper. Consequently, there could be two population foci developed in the Eastern Powder River Coal Basin by 1990 (Table 44, Appendix C).

Employment

Employment projections are based on estimated coal production and facilities (mines, gasification, and power generation) shown in Assumptions and Analysis Guidelines, Chapter II, Part I. County-by-county employment projection figures assume that employment and residence are coincidental, but where anomalies in this assumtion may exist they are pointed out. Projection Tables 45 through 53 (Appendix C) were provided by the Water Resources Research Institute, University of Wyoming, based on the employment and population projection model used for the Northern Great Plains Resource Program social and economic impact study. Figure 10 graphically displays changes in sector employment for the region and Campbell and Converse Counties. Figures 11, 12 and 13 display projected employment and population growth.

Regional employment is impacted by a projected period of employment growth that could be described as enormous for the period 1970 to 1980 and substantial for the period 1980 to 1990 (Table 45, Appendix C).

Total employment for 1970 to 1980 is projected to increase by 41.4 percent (17,060 new jobs) and 20.6 percent (11,985 new jobs) from 1980

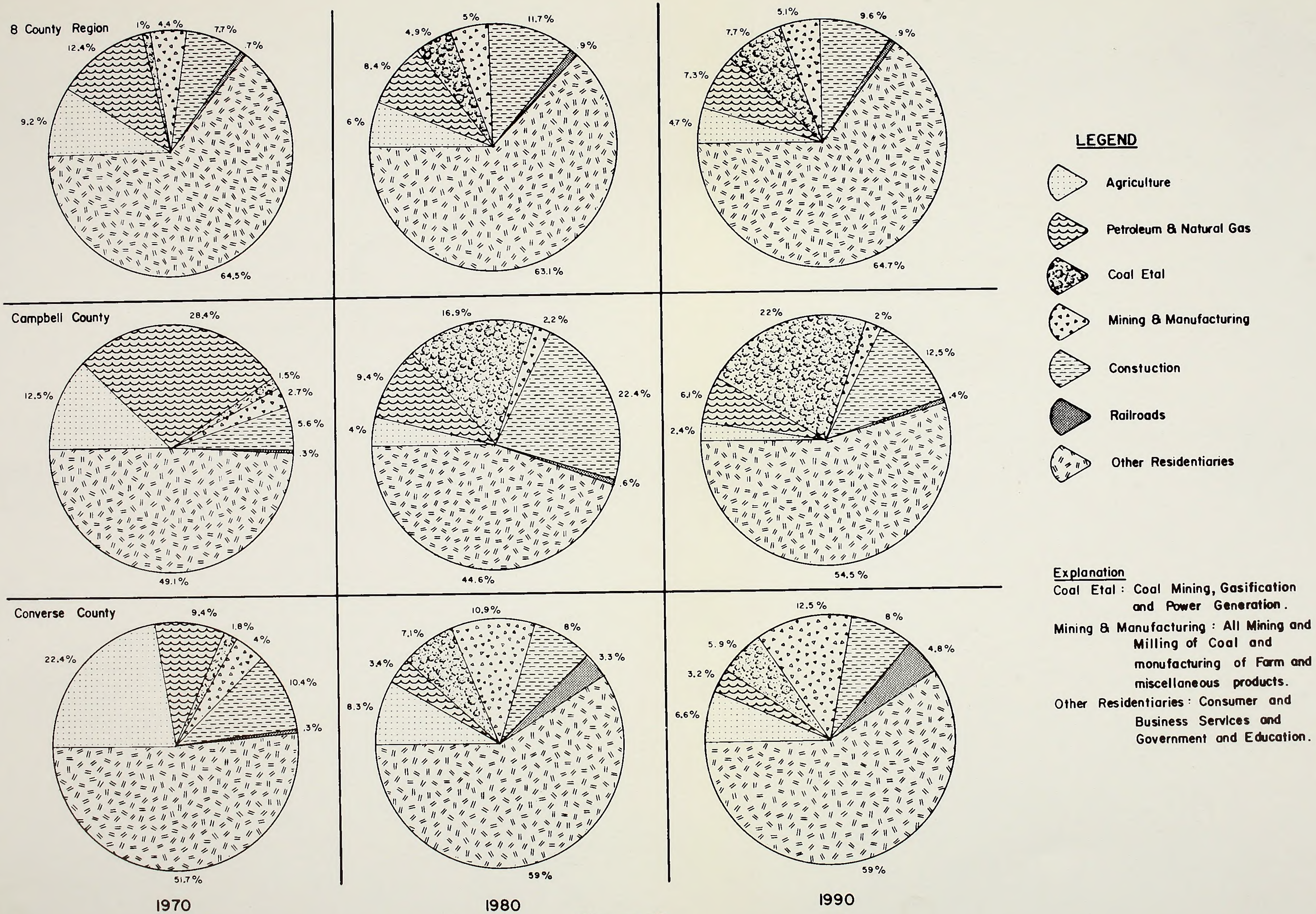

Figure 10
Employment by sectors for 1970,1980 and 1990.

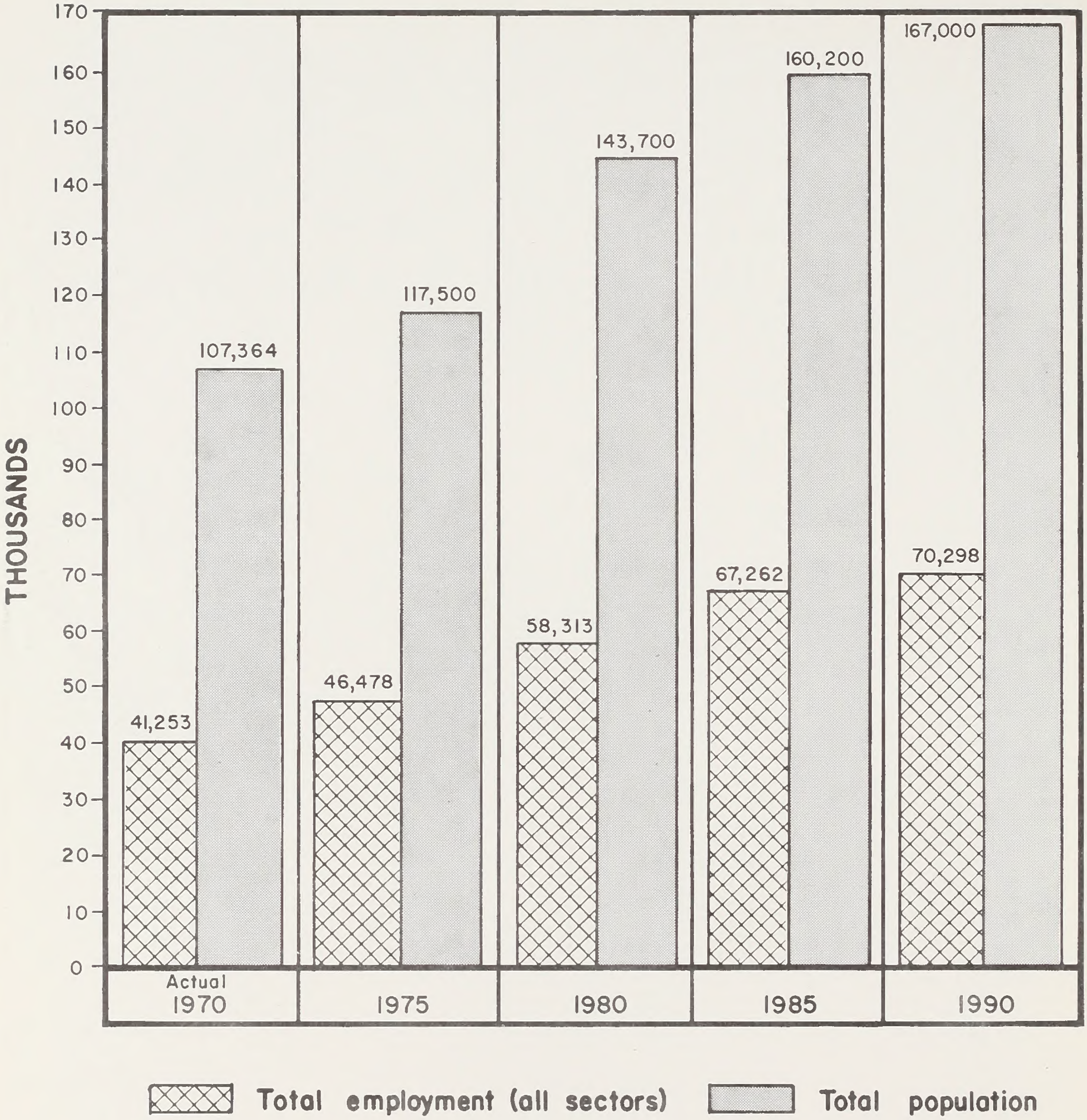

Figure 11

Total Employment and Total Population Projections for the Eight County Region 1970-1990.

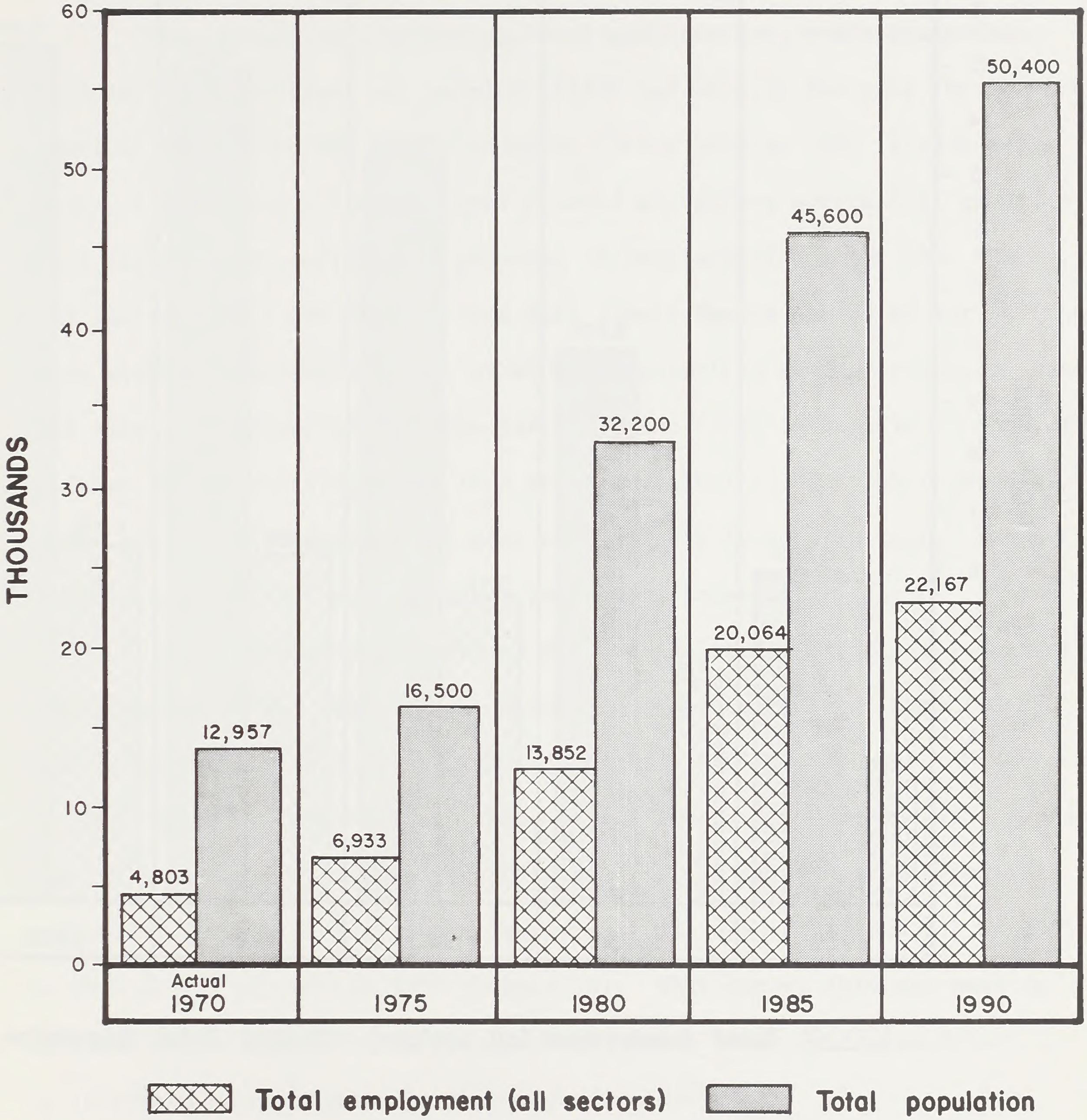

Figure 12
Total Employment and Total Population Projections
for Campbell County 1970-1990.

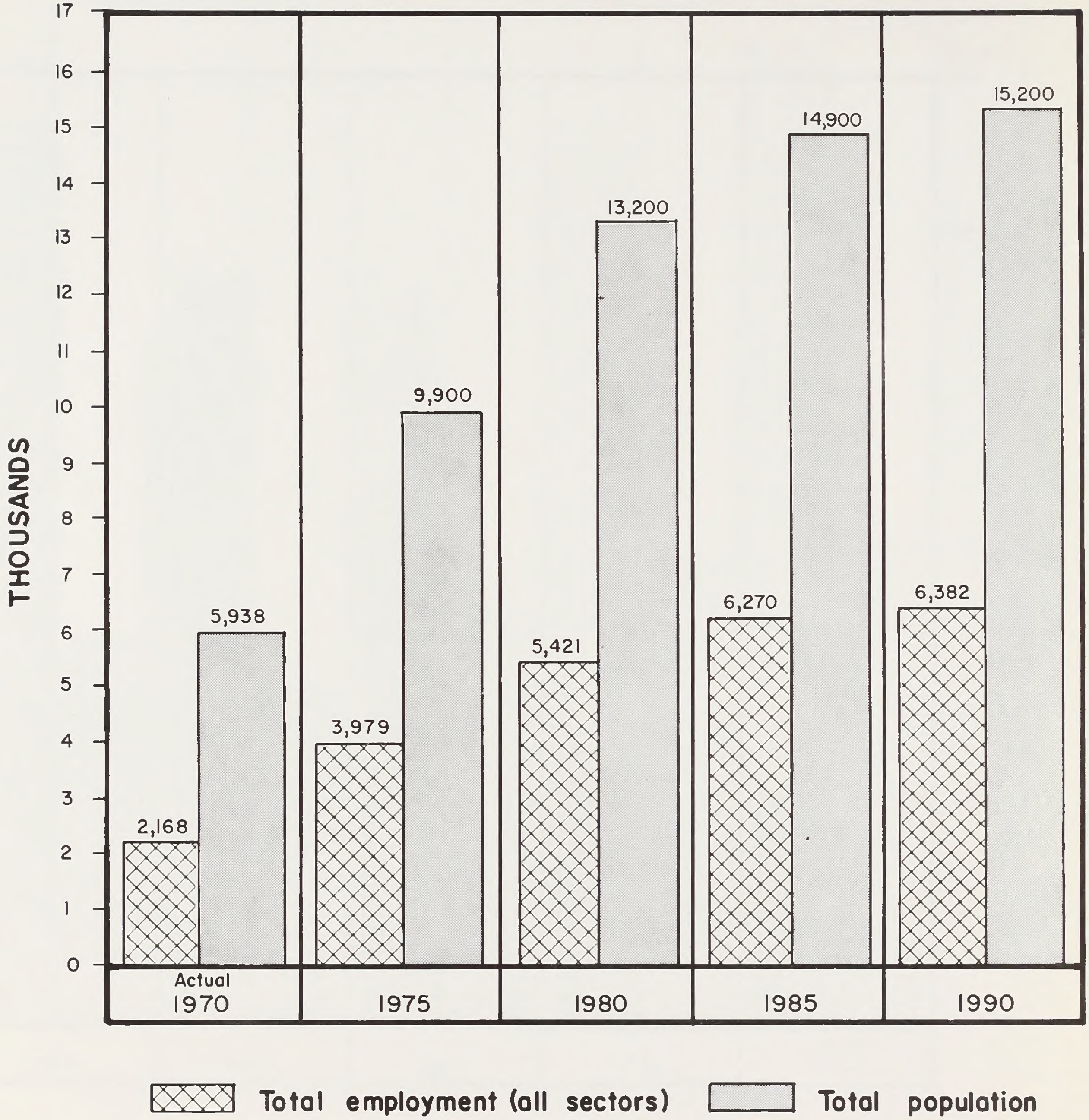

Figure 13
Total Employment and Total Population Projections for Converse County 1970-1990.

to 1990. After 1985 the employment surge begins to taper off due principally to the lack of introduction of any new coal gasification plants (synthetic gas in tables) and a reduced rate of increase of coal mining employment.

Employment in coal mining, coal gasification, power generation, railroads, construction, and uranium mining and milling sustains the greatest numerical and percentage growth increase during 1970 to 1990 (10,019 new jobs). All but the latter are coal related and induce substantial growth in other residentiary sectors. A shortage of available labor for coal mining, coal gasification, and construction will likely induce a bidding war for the labor supply in petrochemicals, other residentiaries, and agriculture. Labor will likely be attracted from the latter to the former. Despite this movement of labor across sectors, there is a strong possibility of a labor shortage in the coal-related sectors and most particularly in construction. Map 6, Appendix A shows coal related labor employment locations.

Certain employment sectors will be impacted as a direct result of coal development and employment. Agriculture may be the most impacted by loss of employment to coal-related industries. Agriculture cannot be expected to offer salaries comparable to those of the energy industry and is expected to lose 12.3 percent of its employment (a loss of 465 employees) between 1970 and 1990. Its share of regional employment will also drop from 9.2 percent in 1970 to 4.7 percent in 1990 (Figure 10). What impact this may have on agricultural productivity is speculative. Labor losses could be offset by increased mechanization or improved efficiency.

The railroad industry, which lost employment between 1960 and 1970 (from 518 to 305) and would be expected to continue this trend without coal freight, will likely reverse this trend and by 1980 employ as many people as it did in 1960.

Impact from coal gasification employment will likely occur initially between 1975 and 1980, requiring about 800 permanent employees. However, greater than this will be the prior demand for construction employees that may reach a peak of 3,000. Construction could take three years per plant.

Construction employees will be in heavy demand which is expected to peak between 1980 and 1985. Large numbers of construction workers will be required through 1990 for construction of coal gasification plants, power generation plants, and housing. The skilled labor required does not appear available in the area in the amount required for peak construction periods.

Impact on other residentiaries is a direct function of employment in the basic sectors (only construction and other residentiaries are considered nonbasic or secondary). Although a precise numerical relationship does not exist between employment in the basic sector plus construction and employment in other residentiaries, a range can be made. For Campbell County (Table 46, Appendix C) for the years 1970 through 1990, the ratio of basic plus construction employment to total employment ranges from 0.56 to 0.45. Thus, one additional employee in a basic sector (coal, etc.) induces a total employment of 1.8 to 2.2 persons, the difference being attributable to other residentiaries. The figures are not as important as realizing that for each employee in coal mining, coal gasification or power generation, an additional employee position is induced in other residentiaries. Filling employment in this sector will lag behind employment in energy industries due to attraction of the available supply of labor to higher paying energy jobs. This opportunity for movement is generally considered beneficial to the employee. It should be emphasized that it will be difficult to fill jobs in the services sector (such as law enforcement) where salaries are fixed with no allowance for areas of inflated incomes. The consequences could be recruitment problems, inferior personnel and understaffing.

In summary, development of the coal resource will provide a large number of basic and secondary jobs, perhaps as many as 30,000 by 1990, which will compete fiercely for the available supply of labor. Skilled labor shortages

for construction peaks during coal gasification plant and generating plant construction may be severe and could be worsened by simultaneous plant construction. Impact identification on a county by county basis further isolates the location of these impacts.

Campbell and Converse Counties

Campbell County, and principally the City of Gillette, will likely experience the most impact within the eight-county region (Tables 54 through 56, Appendix C). The county is projected to experience significant employment growths in coal gasification, coal mining, power generation, railroading and construction from a total of 351 employees in 1970 to 5,523 in 1980 (Table 46, Appendix C). This is a change of 7.4 percent of county employment to 39.9 percent. The bulk of total regional employment in coal mining, coal gasification, power generation, and construction is expected in Campbell County. With a 1970 unemployment level of 2.6 percent, there is an obvious shortage of available labor.

The economic structure of Converse County is likely to be impacted. Agriculture will no longer be dominant and will fall from 22.4 percent of county employment in 1970 to 8.3 percent in 1980 and 6.6 percent in 1990 (Figure 10, this chapter; and Table 47, Appendix C). In its place will be an economy based more on energy and railroad transportation. Power generation and coal mining, which employed 39 persons in 1970, are expected to employ 382 in 1980. The bulk of railroad employment will occur in Converse County. Uranium mining and milling, however, is expected to become the primary employment sector by 1980. One significant change could largely alter the impact on Converse County. The change of the location of one of the coal gasification plants from Campbell County to Converse County would

make coal related employment in mining, gasification, power generation, railroads, and construction the largest employer in the county. Thus, employment impacts would change from being principally noncoal related to directly coal related, which would require the importation of a large amount of labor to fill employment vacancies with subsequent impacts on other socio-economic sectors discussed and most immediately population and housing. Converse County could conceivably be placed in the position where a large number of its residents are commuting and employed outside the county if the coal gasification plant is located in southern Campbell County.

Crook, Johnson, Natrona, Niobrara, Sheridan, and Weston Counties

Crook, Johnson, and Sheridan Counties play an insignificant role in the coal development projected to take place in Campbell and Converse Counties and show no change in employment directly attributable to it. Johnson and Sheridan Counties are, however, potentially impacted by coal development within Johnson County and southern Montana, but an analysis of this impact is beyond the scope of this statement.

Table 50, Appendix C, projects rather moderate growth for Natrona County through 1990, but this growth is only partially attributable, if at all (and only secondarily), to coal development. Any impacts on employment in Natrona County from coal development are considered minor.

Niobrara County, like Crook, is faced with little impact from energy development. However, there is one firm proposal to ship coal via a slurry pipeline that could create a number of temporary and permanent jobs within the county. Few specifics, other than those cited within the

Modes of Distribution section, Chapter II, Part I, are known at this time. A preliminary estimate of 1,000 construction workers will be needed for two years, and a permanent crew of 200 will be employed.

Impact on Weston County, like Niobrara, is dependent on construction of a transportation link. The impact depends entirely on construction of a highway between Newcastle and Reno Junction in Campbell County (Tables 48 through 52, Appendix C).

Income

Income levels for the entering coal or industrial worker will range from $10,000 to $15,000 per year. Whether or not these incomes are sufficiently attractive to lure employees to the Eastern Powder River Coal Basin is unknown. While incomes of the industrial workers will be high, incomes of the work force in supportive employment, e.g., government services and consumer services, may be relatively lower. The average income of the induced labor force will be greater than or at least equal to that of the region ($10,900). The effects of rising incomes and probabey inflation of prices and property values will be particularly adverse on that portion of the population living on fixed incomes, such as disabled, aged and welfare recipients. Although this condition is almost universal, rapid industrial growth could likely worsen the situation.

The Gross Regional Product (GRP) for the Powder River Basin will increase from an estimated 1970 level of $730,000,000 to a projected 1990 level of $1,240,000,000 to $1,410,000,000 (current dollars). Gross Regional Product is an income accounting tool which measures annually the value of economic goods and services. The estimated GRP was derived from data in a 1972 report of the Wyoming Department of Economic PLanning and Development (Burnett 1972, p. 2). Civilian income represents the income received by people for participation in current production (Burnett 1972, p. 12). Gross Regional Product is the product of employment and mean income when divided by the proportion of the civilian income to gross national product (Burnett 1972, p. 2).

The 1990 Gross Regional Product was computed for additional employment at the present regional mean income of $10,900 and at $15,000 per coal worker. As incomes for supportive employment are likely to approximate the mean income and given the anticipated relatively high income of the incoming industrial worker, a range for the 1990 GRP was developed.

Housing

Table 17 displays projected housing demand from 1980 to 1990 in five-year increments by county, urban, and rural areas within each county. Implicit in these projections are four major assumptions: (1) Those employees who work in a given county also reside in that county, (2) the incoming labor force will prefer to locate in urban and rural areas similar to the existing location patterns of 1970, (3) the percentage of urban and rural housing by county has been projected for the future at 1970 levels, and (4) projections of housing demand are based on 1970 household size for each respective city, rural area, and county. Because it is difficult to identify the location and commuting patterns of the arriving work force, these assumptions based on 1970 levels, have been used. Furthermore, these projections underestimate the housing demand of the population as they have not been increased to account for the vacancy rates which would occur in the housing market.

The housing demand for the study area will be 46,400 units in 1980 and 53,500 units in 1990 relative to the 1970 base of 37,463. Approximately 8,900 more units will be required regionally in 1980 than existed in 1970 to meet the rising population and resultant demand. The 1990 housing demand is 6,000 units more than 1970 totals and 7,100 units more than existed in 1980. The greatest increases in housing demand will occur in Campbell and Converse Counties, primarily due to coal and other energy related development. Of the remaining six counties only Natrona and Johnson show a demand that

Table 17

Difference between Projected Housing Demands and 1970 Housing Stock by County of the Powder River Basin, Wyoming*

County***	1970 Stock	1980 Demand**	1980 1970-1980 Difference	1985 Demand**	1985 1970-1985 Difference	1990 Demand**	1990 1970-1990 Difference
Campbell	3,937	9,500	-5,600	13,400	-9,500	14,800	-10,900
Gillette	2,228	5,400	-3,200	7,600	-5,400	8,400	- 6,400
Rural	1,709	4,100	-2,400	5,800	-4,100	6,400	- 4,700
Converse	2,247	4,400	-2,200	5,000	-2,800	5,100	- 2,900
Douglas	1,029	2,000	-1,000	2,300	-1,300	2,300	- 1,300
Rural	1,218	2,400	-1,200	2,700	-1,500	2,800	- 1,600
Crook	1,576	1,400	200	1,400	200	1,400	200
Urban	-----	-----	------	------	------	------	--------
Rural	1,576	1,400	200	1,400	200	1,400	200
Johnson	2,158	2,600	- 400	2,600	- 400	2,600	- 400
Buffalo	1,319	1,600	- 300	1,600	- 300	1,600	- 300
Rural	839	1,000	- 200	1,000	- 200	1,000	- 200
Natrona	17,228	19,000	-1,800	19,500	-2,300	19,900	- 2,700
Casper	13,426	14,800	-1,400	15,200	-1,800	15,500	- 2,100
Rural	3,802	4,200	- 400	4,300	- 500	4,400	- 600
Niobrara	1,330	1,000	300	1,000	300	1,000	300
Urban	------	------	------	------	------	------	--------
Rural	1,330	1,000	300	1,000	300	1,000	300
Sheridan	6,799	6,500	300	6,600	200	6,600	200
Sheridan	4,434	4,200	200	4,300	100	2,300	100
Rural	2,365	2,300	100	2,300	100	2,300	100
Weston	2,188	2,000	200	2,000	200	2,100	100
Newcastle	1,268	1,100	200	1,100	200	1,200	100
Rural	920	900	------	900	------	900	--------
Study Area	37,463	46,400	-8,900	51,500	-14,000	53,500	-16,000

*Demand and Difference between Projection Years and 1970 Stock rounded to nearest hundred.
**Population per occupied housing unit derived from Table I for each respective county and held constant from 1980-1990.
***The percentage of urban and rural housing by county has been projected at 1970 levels.

will necessitate the construction of additional housing units assuming that the present housing stock remains in use. The other four counties will experience a decreased housing demand relative to 1970 levels.

Campbell County

Campbell County will require approximately 9,500 units in 1980 which is 5,600 units more than the 1970 total of 3,937 units. By 1990 the population of Campbell County will demand 14,800 housing units which is 10,900 units more than the prevailing stock in 1970 and 5,300 units more than the estimated 1980 stock. Thus, the housing stock in Campbell County by 1990 will need to expand by nearly four times to meet the anticipated demand.

Converse County

Converse County will have an estimated housing demand of 4,400 units in 1980 and 5,100 units in 1990. The 1980 demand is about 2,200 units more than the existing 1970 stock of 2,247 units, and the 1990 demand is 2,900 units more than 1970 levels and 665 units more than estimated 1980 levels. The housing stock by 1990 must more than double to meet the anticipated demand.

Crook, Johnson, Natrona, Niobrara, Sheridan, and Weston Counties

Johnson and Natrona Counties will experience a growing population which will necessitate the construction of new housing, while the other four counties will need no additional new housing other than that existing in 1970. The population of Johnson County will demand 2,600 units by 1980 and continue to demand that same number of units by 1990. As population in Johnson County by 1990 will decrease relative to 1980, the housing stock having expanded by 400 in 1980 as compared to 1970 levels will be more than

sufficient to fulfill 1990 demands. Natrona County will have an estimated housing demand of 19,000 by 1980 and 19,900 by 1990 compared to the 1970 total of 17,228 units. Niobrara County will encounter a housing demand in 1990 of 1,000 units which is approximately 25 percent less than the 1970 housing stock of 1,330.

Cost of new housing

The influx of a work force with associated families will create an immediate housing demand in the Counties of Campbell, Converse, Johnson, and Natrona. At present levels, the supply of housing in these counties is inadequate to meet the projected housing demands. Consequently, new housing would be required if the demand is to be met.

The cost of a typical single-family residential unit in the Eastern Powder River Coal Basin based on 1972 data can be expected to vary from \$26,000 to \$39,000 for a range of 1,000 to 1,500 square feet. These estimates have been developed using data furnished by the National Association of Home Builders (NAHB) and interviews conducted with banks and builders in Cheyenne, Wyoming (Table 57, Appendix C).

Ability of consumers to pay for housing

Households of the entering population with a gross income ranging from \$10,000/year to \$18,000/year can be expected to correspondingly purchase housing of \$18,000 to \$33,000. These estimates have been based on (1) interviews with three major banks in Cheyenne, Wyoming, (2) current interest rates, (3) a five-percent down payment, (4) a 30-year mortgage, and (5) an expenditure of about 25 percent of the gross monthly income on housing related items including mortgage, interest, property taxes, and insurance. The amount of housing the entering worker and his family can reasonably afford to purchase is

dependent on income and overall financial status. As it is difficult to assess the wealth of the arriving population by family, the above estimates of the amount of housing that a family may purchase is thus more reliant on annual income.

Responsiveness of the housing market
to predicted housing demand

The housing market will be unresponsive to projected housing demand as the price of new housing will exceed the ability to pay for most of the arriving work force, except for the higher income levels ($15,000/year and higher), which can afford houses no larger than 1,200 square feet. Because the incoming population will have incomes generally insufficient to stimulate housing production, a shortage of housing may result. The arriving population, when confronted with an inadequate supply of housing, will bid up the prices of the current stock. Additionally, the entering population as well as those displaced by the higher prices may seek alternative forms of housing, namely the mobile home.

A critical housing situation will exist when the population related to coal development in Campbell and Converse Counties enters the region. As the median value of an owner-occupied home in 1970 in the eight-county study area was approximately $16,000, it would seem that the entering population would be able to afford housing within its financial capabilities. The problem is that the entering population will be so numerous and have incomes insufficiently high that the current supply will be unable to expand and absorb the demand generated by the arriving population. There will be a shortage of permanent homes in the region, especially in Campbell and Converse Counties where the price of new conventionally built housing exceeds that which a majority of the arriving population can be expected reasonably to

pay. People in income levels between $10,000/year to $18,000/year will not be able to purchase a home larger than 1,300 square feet. Households with incomes greater than $15,000/year will be able to purchase housing but the living area will likely be no greater than 1,000 to 1,200 square feet.

Since there will be an influx of new population which in the whole have incomes deficient to generate a housing market response, there will appear dislocations due to price or changes in present housing consumptive patterns. In this instance, the entering work force characterized by incomes greater than the existing average will bid prices up for all units. Many owners of single-family homes will prefer to sell their homes at a substantial profit, while renters of single-family and multifamily units may be required to move as prices rise to levels they are no longer willing and able to pay. To obtain housing they can afford within the same community, former renters may accept housing which may be substandard. The shortage of housing will necessitate maintenance of substandard units in the housing stock, although these substandard housing units otherwise would have dropped out of circulation had not the demand for housing dramatically risen, given a relatively inelastic supply. Other families may select housing units of lesser sizes which may lead to overcrowded conditions. At present, 13.2 percent of the population in Campbell County live in housing considered overcrowded. This percentage would be elevated further as individual households respond to the changing housing market. Finally, many families may select the mobile home as the only means by which to solve their housing demands.

The mobile home satisfies housing demand more in the short than long term. While the life of a mobile home can vary substantially depending on make and model, climate, and care taken by its occupants, some indication

of its expected life is suggested by the typical financing period of 7 to 12 years as compared to the 30-year (or longer) mortgage available for purchase of conventional single-family homes (U.S. Congress, House 1968, p. 439). The mobile home depreciates much more rapidly than the conventionally built home because of its lighter construction and the obsolescence of nonreplaceable built-in elements (President's Committee on Urban Housing 1968, p. 156).

The City of Gillette is a clear historic example where a sudden, arriving population could not locate housing and necessarily resorted to the purchase of mobile homes. In 1970, 42.3 percent of the total year-round housing stock was mobile homes. If the mobile home is the only form of housing available at the price the incoming population is willing to pay, the percentage of mobile homes in the total housing stock will increase greatly. If the housing mix becomes such that mobile homes constitute 50 percent or more of the housing stock in Gillette and Campbell County and given the short expected life of the mobile home relative to the conventional home, there exists the potential of widespread deterioration on an enormous scale after at least two decades. Further, as there are no controls on the quality of mobile homes sold in the state, it is quite likely that mobile homes would be of a lesser quality than where such controls exist. The adverse impact resulting from no state controls would be the purchase of mobile homes which could be dangerous under certain climatic conditions. Because construction would be of lower quality, the rate of depreciation would be accelerated.

The Denver Office of the Department of Housing and Urban Development has suggested to the Casper Office of the Federal Housing Administration that the present share of mobile homes in Campbell County is highly disproportionate and that more mobile homes should be actively discouraged. While more mobile homes could be purchased regardless of HUD-FHA policy suggestion, it is interesting to note that if new mobile homes could be discouraged while conventionally built homes remain too expensive, the only alternative housing types would be townhouses and apartments. Apartments would be suitable for single individuals and married couples but probably too confining for large families. HUD-FHA has recommended that efforts in the future be directed toward apartments and sales units. Sales units could include condominiums and cooperatives on small scale to test the market. If the public preference for housing could shift from single family detached to single family attached units and multifamily units, then perhaps the housing demands of the incoming population can be satisfied.

Conclusion

The majority of the arriving population probably cannot afford new housing which will create a severe housing problem, especially in Campbell and Converse Counties. As individuals respond to the lack of available housing, they will accept inferior housing quality and living conditions and/or select the mobile home as a housing alternative. The mobile home may prove adequate as short-term housing but does not compare to the durability of the conventionally built home. Unless other housing forms are introduced and accepted, the

mobile home will become the dominate form of housing in Campbell County and to a lesser extent in Converse County.

Public education

Development of coal and energy-related resources in the study area will cause an increase in the regional population between now and 1990. With a rise in population levels and immigration of various work forces with associated families, public school enrollments will realize substantial increases in Campbell and Converse Counties. Increasing student enrollments in turn would impact enrollment capacities of existing school district facilities and teaching staffs.

In order to determine student enrollment projections for 1980, 1985, and 1990, certain factors had to be assumed. The projections are based on the following demand factors and assumptions which are explained further in Appendix C:

1. There will be 250 families per 1,000 population; each family unit will consist of 3.5 persons. (The difference is single people.)

2. Each family unit will reside in the county in which its head of household will be employed.

3. There will be 1.0 school age child per family unit or 250 school age children per 1,000 population.

4. The number of school age children per family by school grade level is provided below:

Type of School	Grade Levels	Number of School Age Children per Family
Elementary	K-6	0.50
Junior High	7-9	0.25
Senior High	10-12	0.25

Enrollment projections and distribution

Table 18 displays student enrollment projections and distribution in the region for the 1980 to 1990 period. Enrollment projections have been aggregated at the county level for those counties with more than one school district since it is difficult to determine in which school district incoming families will establish residency.

As indicated in Table 18, Campbell and Converse Counties will experience the most substantial impact from student enrollments. Between 1974 and 1990, school enrollments would more than quadruple in Campbell County from 3,022 to 12,660 and more than double in Converse County from 1,842 to 3,875. Johnson, Natrona, and Sheridan Counties would experience moderate increases, while school enrollments would remain relatively stable in Crook, Niobrara, and Weston Counties.

The distribution of public school children (Table 18) will also change substantially in the region. At present, Natrona County has the largest share (41.3%) of the regional student enrollment total; however, by 1990, the Natrona figure will shrink to 36.9 percent. This reduction can be attributed primarily to increasing school enrollments in Campbell and Converse Counties. Campbell County, which currently has 11.3 percent of the regional enrollment total, will assume a significant educational role by the year 1990 with over 30 percent of the region's total enrollment.

Impacts on existing school facilities and full-time teacher staffs

By 1980, the influx of a work force (including temporary construction and permanent workers) and associated families would place significantly large demands on school enrollments of school districts in Campbell and Converse Counties. At present, the capacities of existing schools and

Table 18

Enrollment Projections and Distribution
Powder River Basin Region
1980-1990

	Actual 1974	Percent Region Total	1980	Percent of Region Total	1985	Percent of Region Total	1990	Percent of Region Total
Campbell	3,022	11.3	8,050	22.4	11,400	28.5	12,600	30.1
Converse	1,848	6.9	3,300	9.2	3,725	9.3	3,875	9.3
Crook	1,178	4.4	1,125	3.1	1,150	2.9	1,150	2.7
Johnson	1,224	4.6	1,875	5.2	1,850	4.6	1,850	4.4
Natrona	13,181	49.3	14,750	41.1	15,100	37.7	15,450	36.9
Niobrara	604	2.2	700	1.9	675	1.7	650	1.6
Sheridan	4,027	15.1	4,550	12.7	4,575	11.4	4,625	11.1
Weston	1,671	6.2	1,575	4.4	1,575	3.9	1,625	3.9
Region Total Enrollment	26,755	100.0	35,925	100.0	40,050	100.0	41,825	100.0

number of full-time teachers in these counties would be totally inadequate to cope with enrollment projections for 1980 to 1990. While Sheridan, Johnson, and Natrona Counties would continue to operate near maximum capacity levels, school districts in Crook, Niobrara, and Weston Counties would realize very minimal changes in 1980 to 1990 enrollments and would operate below maximum capacity levels by more than 25 percent.

Campbell County. The most significant impacts on public education would take place in Campbell County which would realize a phenominal 300 percent enrollment increase between 1974 and 1990. Table 19 provides a detailed analysis of the impacts of increasing enrollments on existing school capacities and full-time teaching staffs. The most critical period of student enrollment growth would occur between 1974 and 1980, when enrollment would increase by 166.4 percent from 3,022 to 8,050 students. Existing school facilities and teaching staffs would be unable to absorb this large increase. By 1980, school enrollments would exceed maximum capacity levels by 97.5 percent in elementary schools and 82.7 percent in both junior high and senior high schools. The school district would require approximately 200 more full-time teachers and school facilities with enrollment capacities to accommodate an additional 3,810 students, which includes 1,990 elementary, 910 junior high, and 910 senior high school students.

By 1990, the enrollment capacity and existing number of full-time teachers would need to triple in order to accommodate the projected enrollment of 12,600 students.

Converse County. The Douglas and Glenrock school districts in Converse County would realize a 109.7 percent increase in student enrollments between 1974 and 1990. Table 20 details the impacts of increasing enrollments on existing school capacities and full-time teacher staffs.

Table 19

Campbell County Unified School District
Enrollment Projections, Capacity Levels, and Teacher Needs

	Actual 1974*	Projections 1980	1985	1990
Total Enrollment				
Projected Number of Pupils**	3,022	8,050	11,400	12,600
Number over (+), under (-) capacity***	- 768	+3,810	+7,160	+8,360
Percent over or under capacity	-20.3%	+89.9%	+168.9%	+197.2%
Elementary Enrollment (K-6)				
Projected Number of Pupils#	1,722	4,030	5,700	6,300
Number over (+), under (-) capacity	- 318	+1,990	+3,660	+4,266
Percent over or under capacity	-15.6%	+97.5%	+179.4%	+208.8%
Junior High Enrollment (7-9)				
Projected Number of Pupils	699	2,010	2,850	3,150
Number over (+), under (-) capacity	+ 49	_ 910	+1,750	+2,050
Percent over or under capacity	+ 7.5%	+82.7%	+159.1%	+186.4%
Senior High Enrollment (10-12)				
Projected Number of Pupils	601	2,010	2,850	3,150
Number over (+), under (-) capacity	- 499	+ 910	+1,750	+2,050
Percent over or under capacity	- 45.4%	+82.7%	+159.1%	+186.4%
Full-time Teachers				
Projected Number Required##	204	405	570	630
Deficit###	0	- 201	- 366	- 426

*1974 figures represent existing levels in enrollments and teaching staffs.
**Refer to Appendix C, Table 70 for derivation of projections.
***1974 maximum enrollment capacity total equals 3,790, which includes 2,040 elementary, 650 junior high and 1,100 senior high student enrollment capacities. By 1980, the maximum enrollment capacity total will be 4,240 with an increase in junior high school enrollment capacity to 1,100 students.

#Includes figures for rural schools (grades K-8).
##Based on students to teacher ratios of 20 to 1.
###Based on Fall 1973 level of 204 full-time teachers.

Table 20

Converse County Unified School District #1 (Douglas) & #2 (Glenrock)
Enrollment Projections, Capacity Levels, and Teacher Needs

	Actual	Projections		
	1974*	1980	1985	1990
Total Enrollment				
Projected Number of Pupils**	1,848	3,300	3,725	3,875
Number over (+), under (-) capacity***	- 272	+ 750	+1,130	+1,280
Percent over or under capacity	-12.8%	+27.2%	+43.5%	+49.3%
Elementary Enrollment (K-6)				
Projected Number of Pupils#	998	1,650	1,865	1,935
Number over (+), under (-) capacity	- 172	+ 305	+ 520	+ 590
Percent over or under capacity	-14.7%	+22.7%	+38.7%	+43.9%
Junior-Senior High Enrollment (7-12)				
Projected Number of Pupils	850	1,650	1,860	1,940
Number over (+), under (-) capacity	- 100	+ 400	+ 610	+ 690
Percent over or under capacity	-0.8%	+48.8%	+48.8%	+55.2%
Full-Time Teachers				
Projected Number Required##	92	165	186	194
Deficit###	0	- 62	- 83	- 91

*1974 figures represent existing levels in enrollments and teaching staffs.
**Refer to Appendix C, Table 71 for derivation of projections.
***1974 maximum enrollment capacity total equals 2,120 which includes 1,170 elementary and 950 junior-senior high student enrollment capacities. By 1980, the maximum enrollment capacity total will be 2,595 with an increase in elementary enrollment capacity to 1,345 and junior-senior high enrollment capacity to 1,250.

#Includes figures for rural schools (K-8).
##Based on students to teacher ratio of 20 to 1.
###Based on Fall 1973 level of 103 full-time teachers.

Like Campbell County, the most substantial increase in Converse County enrollments would take place between 1974 and 1980. Enrollments would increase by 78.6 percent from 1,848 to 3,300 students, and existing school enrollment capacities and full-time teacher staffs would not be able to adequately support this increase. By 1980, school enrollments would exceed present capacity levels by 22.7 percent in elementary schools and 32 percent in junior-senior high schools. The school districts would need approximately 60 additional full-time teachers and accommodations for 705 additional students--305 pupils in grades K-6 and 400 junior-senior high school students.

By 1990, the school districts would require a 50-percent increase in present enrollment capacity levels and twice as many existing full-time teachers in order to accommodate the projected enrollment of 3,875 pupils, which include 1,935 elementary and 1,940 junior-senior high school students.

Johnson County. Table 78 in Appendix C, shows the impacts of increasing enrollments on existing school facilities and full-time teacher staffs. Between 1974 and 1980, the Johnson County unified school district would experience a significant 53.2 percent increase in school enrollments from 1,224 to 1,875 students. By 1980, school enrollments would slightly exceed maximum capacity levels by 13.1 percent in elementary schools and only 4.2 percent in junior-senior high schools. The school district would need only one more full-time teacher and additional facilities for 170 more students. After 1980, school enrollments would decrease slightly and, thus, impose no additional requirements upon the school district.

Sheridan, Natrona, Crook, Niobrara, and Weston Counties. Population increases due to coal and energy related developments in the region will

have very minimal, if any, impacts on public education in these counties. Tables 79 through 83 in Appendix C provide the status of existing school facilities and full-time teacher staffs in relation to student enrollment projections for 1980 through 1990. During this time period, school districts in Crook, Niobrara, and Weston Counties will sustain rather stable enrollments. However, if substantial commuting for employment purposes occurs across county lines, particularly from Crook to Campbell County, this prediction could change. Small school districts, like Moorcroft, could have substantial impact from a rather small enrollment increase.

Although the scope of this report does not include the Montana portion of the Powder River Basin, it should be pointed out that school enrollments in Sheridan County would be affected by work force populations associated with coal-energy-related developments in Montana. For the purposes of this report, however, Sheridan County enrollment projections have been based solely on anticipated population changes resulting from developments in Wyoming.

Summary. Table 21 provides a summary of needs for full-time teachers and enrollment capacities to meet projected student enrollment demands for 1980, 1985, and 1990. The combined needs of Campbell and Converse Counties would include the largest share of the region's full-time teacher deficit and enrollment over capacity total. By 1990, the region would require 533 additional teachers and increases in enrollment capacities to accommodate 11,235 additional students. The regional teacher deficit level and enrollment over capacity total would double between 1980 and 1990.

School districts in Campbell and Converse Counties would realize the regions most substantial impacts on existing enrollment capacities and teaching staffs. If these districts do not provide accommodations for increasing enrollments, then the following impacts could result:

Table 21

Summary of Full Time Teacher Deficits and
Enrollments over Existing School District Capacities

School Districts By County	1980		1985		1990	
	Full Time Teacher Deficit*	Enrollment over Capacity**	Full Time Teacher Deficit*	Enrollment over Capacity**	Full Time Teacher Deficit*	Enrollment over Capacity**
Campbell	201	3,810	366	7,160	426	8,360
Converse	62	705	83	1,130	91	1,280
Crook	-	-	-	-	-	-
Johnson	1	170	-	145	-	145
Natrona	-	750	-	1,100	4	1,450
Niobrara	-	-	-	-	-	-
Sheridan	8	-	10	-	12	-
Weston	-	-	-	-	-	-
Regional Totals	272	5,435	459	9,535	533	11,235

*Full time teacher deficits equal projected demands minus 1973 levels.

**School enrollments are over capacity when student enrollment projections exceed 1975-75 maximum enrollment capacity levels.

1. Classroom sizes would quickly reach capacity and necessitate very high students to teacher ratios;

2. Due to overcrowded conditions and the lack of classrooms in existing school facilities, it may be necessary to use temporary structures such as mobile trailers and modular units;

3. The lack of classrooms and adequate space (gymnasium, play areas) could cause a school district to operate certain schools on a double session basis;

4. Inter-county bussing of students between school districts could result and become necessary; and

5. The quality of education could be affected adversely.

Health and social services

Development of the Eastern Powder River Coal Basin and its attendant population increase will seriously impact several elements of the health and social service systems. Elements already in scarce supply will be most severely impacted.

Health

Existing manpower, facilities, and services will be most impacted by the sheer volume of increase in population.

Manpower. The study area is already short of personnel in virtually all health manpower categories. With the exception of Natrona and Sheridan Counties, the region has few physicians, dentists, nurses (both R.N. and L.P.N.), and optometrists to serve the existing local population. Projected population increases will thus intensify an already serious situation.

Table 22 presents the number of personnel engaged in each of ten health fields for each of the eight counties in the area. Based upon current manpower to population ratios for the State of Wyoming and recommended ratios for the nation as a whole, a set of manpower requirements was estimated for

Table 22

Projected Needed Health Manpower

	Physicians				Dentists				Registered Nurses			
	Existing	Deficiency			Existing	Deficiency			Existing	Deficiency		
	1970	1970	1980	1990	1970	1970	1980	1990	1970	1970	1980	1990
Campbell	7	6-7	25-28	43-48	3	3-5	12-17	21-28	30	15-30	83-121	147-207
Converse	4	2	9-10	11-13	2	1-2	4-6	5-7	24	0-4	22-38	29-47
Johnson, Natrona, Sheridan	96	0	0	0	41	0-5	0-12	0-14	433	0	0	0
Crook, Niobrara, Weston	5	9-10	9-10	9-10	3	3-6	3-6	3-6	45	3-20	3-19	3-19

	Licensed Professional Nurses				Optometrists				Sanitarians**			
	Existing	Deficiency			Existing	Deficiency			Existing	Deficiency		
	1970	1970	1980	1990	1970	1970	1980	1990	1970	1970	1980	1990
Campbell	13	4-8	30-39	54-69	2	0	2-3	4-5				
Converse	5	3-5	12-16	15-20	1	0	1	1				
Johnson, Natrona, Sheridan	157	0	0	0	8	0-3	0-4	3-5				
Crook, Niobrara, Weston	11	7-12	7-12	7-12	2	0	0	0				
Dist. #3*									6	0	0-2	0-3
Natrona									3	0	0	0-2

Table 22 Cont'd

Table 22 Cont'd

	Pharmacists				School Nurses			
	Existing	Deficiency			Existing	Deficiency		
	1970	1970	1980	1990	1970	1970	1980	1990
Campbell	7	4	21	36	5	0	0	3
Converse	5	0	6	8	2	0	0	0
Johnson, Natrona, Sheridan	72	0	1	3	13	0	0	1
Crook, Niobrara, Weston	6	6	5	6	1	1	1	1

	Public Health Nurses				Dental Hygienists			
	Existing	Deficiency			Existing	Deficiency		
	1970	1970	1980	1990	1970	1970	1980	1990
Campbell	2	0	2	4	2	0	0	2
Converse	0	1	2	2	0	0	1	1
Johnson, Natrona, Sheridan	7	2	2	2	12	0	0	0
Crook, Niobrara, Weston	0	2	2	2	0	0	0	0

*Includes all counties but Natrona for sanitation.

**If development includes considerable reliance on mobile homes, particularly in fringe areas, sanitarian requirements will be slightly higher than the upper end of the indicated range.

Source: Wyoming Health Profiles, 1972, Department of Health and Social Services.

Table 22 Cont'd

the period 1980 to 1990. Relying upon the above discussed population projections generated by the University of Wyoming model, manpower requirements are calculated as a function of population. Table 22 presents manpower requirements for each of the eight counties within the region.

Campbell and Converse Counties will be seriously impacted. In 1970 Campbell County had only seven physicians, three dentists, 30 registered nurses, 13 licensed professional nurses, and seven pharmacists. These five manpower categories will be most severely impacted by projected population growth. Likewise, Converse County had only four physicians, two dentists, and five licensed professional nurses. Again, these three areas will be most highly affected by population growth.

Manpower requirements presented in Table 22 are based entirely on population projections. Depending upon local community's ability to provide for the environmental health and safety of new residents, manpower requirements may be somewhat modified. As Table 22 indicates the required number of environmental sanitarians may be greater than that shown. According to the Wyoming Department of Health and Social Services, additional sanatarians will be required in response to uncontrolled development of mobile home parks with inadequate water and sanitation provisions. If such development were to occur, potential hazards to public health and safety would require additional environmental health surveillance.

The remaining six counties in the Powder River Basin region will be less severely impacted. With more gradual population growth, projected manpower requirements can be more readily satisfied. However, here too, existing shortages in the more rural counties may create added difficulties in meeting future needs.

Facilities. The study area currently has an ample supply of health facilites. With few exceptions, the nine hospitals and six nursing care facilities have sufficient capacity to meet present needs.

In projecting future needs, uncertainties as to future utilization rates limited the confidence with which estimates could be generated. The county populations who will be served by health facilities in the area will not necessarily reflect present county utilization patterns. Thus, only regional facility impacts could be calculated. Assuming variations among future county populations will balance out to a level not significantly different from current regional utilization rates, certain regional facility requirements could be calculated. Using the Hill-Burton (78 Stat. 447) formula, approximately 520 and 590 acute beds will be needed in 1980 and 1990, respectively. From the Hill-Harris (84 Stat. 336) formula, approximately 560 and 650 nursing home beds will be needed for these time periods. With a present stock of 495 acute and 557 nursing home beds, the impact of increased bed requirements will not be significant until the 1980-1990 decade.

Services. As with manpower and facilities, services impact will be a direct function of the added demands generated by population growth and the ability of the community to accommodate that growth. Perhaps more than any other service sector, mental health and alcohol treatment will be most sensitive to pressures of rapid development. The effect of such development on the service sector is extremely difficult to predict. The following discussion is thus directed more to general trends than specific points of impact.

Previous periods of rapid development in Campbell County have produced a marked increase in demand for mental health and alcohol treatment

services. Directly related to the stresses produced by rapid development, this past record indicates that if the situation is repeated, the same response is likely to occur. Although a certain amount of variability is due to the predisposing characteristics of the incoming population, the environment into which they come can either intensify or modify these tendencies. Thus, an influx of transient individuals or families, many of whom have pre-existing adjustment difficulties, can create a definite impact on the mental health sector. The degree of impact is, however, a function of the ability of the system to respond to the increased demands placed upon it.

Social services

Based upon past and present conditions generated by rapid mineral related development in such areas as Gillette and Rock Springs, certain general impacts may be noted. The severity of these impacts is, however, dependent upon such variables as the size and composition of the incoming population, the ability of various public service sectors (housing, sanitation, etc.) to accommodate this population, and the psycho-social characteristics which enable these newcomers to adjust to a new and unfamiliar environment.

Population projections indicate that a relatively large proportion of newcomers will be unattached males employed in the construction or mining industries.

These individuals are not expected to seriously affect the present social service system. Rather, the most serious impact is expected from married couples, either with or without children, who are frustrated by inadequate public services, an increasingly high cost of living (as is common to most boom towns), and a lack of effective recreational opportunities. Unless these factors are mitigated and thereby prevented from creating a climate ripe for

dysfunctional behavior, such social services as child protection and family counseling will be severely impacted.

Campbell County, already seriously affected by these factors, illustrates the strain on an existing social service system. Continued rapid development is expected to intensify the situation. Between 1960 and 1970 the population of Campbell County increased by 121 percent. According to estimates of the staff of the Division of Public Assistance and Social Services (1974), the social service caseload increased by at least 150 percent. Although it is impossible to accurately characterize the incoming population, it may be anticipated that if public and recreational services are not adequately supplied and if the newcomers are fairly similar to their predecessors, an increase in social service caseload on the order of previous such increases will be forthcoming. Moreover, this increase will be particularly severe in child protection services.

Converse County, only beginning to experience the effects of rapid development, may be affected in much the same way. Again, the extent of impact will depend upon the same above mentioned factors, and the most serious impact area will probably be child protection services.

Impact on the remaining six counties will depend upon the amount of incoming population and the ability of the existing social structure to assimilate these newcomers into the community. If population increments are relatively small, the community will be far more likely to accomplish this task. The incidence of dysfunctional families will thus be lower, as will the corresponding need for social services.

It should be noted that although the public assistance function will not be seriously affected by rapid mineral-related development, certain isolated impacts may occur. Although the incoming population will generally be well

paid and self-supporting many residents already on public assistance will remain dependent on such support. The typical increase in the cost of living in such rapidly developing areas will impact most severely on those persons who are on fixed, and generally low, incomes. Recipients of public assistance and social security will thus be seriously affected.

Law enforcement

Development of coal and energy related resources with its attendant rise in population will impact the law enforcement personnel and facilities within the region. With a rise in population and immigration of various types of people, crime rates will change to undeterminable new levels. Based on population projections and standard levels of enforcement personnel per 1,000 population, an estimate can be made of the number of enforcement personnel which would likely be required to provide adequate law enforcement. These projections can be compared to the existing situation, thereby providing some measure of the magnitude of impact.

Sheriff departments

Table 23 presents the full-time manpower projections that would be required for sheriff's departments to meet the increased demand. In the region, Campbell and Converse County sheriff departments will require the most sizeable increases in manpower. At present, sheriff agencies in the remaining six counties (except Sheridan) have reasonably adequate full-time staffs and probably would require minimal, if any, changes to meet the demand by 1990. The major increase in demand occurs in the period from the present time to 1980. The projections indicate that to serve the increased population by 1980, a total of 74 new law enforcement personnel would be required. From 1980 to 1985, the number of personnel required would increase by 17, and

Table 23

Projections for Full Time Manpower* of Sheriff's Departments in Powder River Basin

	1973	Projections 1980		1985		1990	
	Actual	Need**	Deficit***	Need**	Deficit***	Need**	Deficit***
Campbell	8	32	24	46	38	50	42
Converse	6	13	7	15	9	15	9
Crook	5	5	0	5	0	5	0
Johnson	3	7	4	7	4	7	4
Natrona	37	59	22	60	23	62	25
Niobrara	2	3	1	3	1	3	1
Sheridan	4	18	14	18	14	18	14
Weston	4	6	2	6	2	6	2
Region Total	69	143	74	160	91	166	97

*Full time employees include both sworn officers and civilians.

**The state average is 0.6 full time employees per 1,000 population. The national average is 1.0 full time employees per 1,000 population. For the purposes of this report, the national average is used to determine demand levels.

***Deficit based on actual manpower in 1973.

from 1985 to 1990 the increase drops off to six. As population is expected to stabilize beyond 1990, the demand for enforcement personnel is not expected to experience any rapid rise.

The Wyoming State Highway Patrol will also be impacted. Increased traffic flow would in all probability necessitate a corresponding increase of patrol personnel. However, it is difficult to determine how much of an increase may be required to provide an adequate level of service and coverage. Most of the law enforcement burden would be borne by local and county agencies.

Campbell County Sheriff's Department. By 1980, the existing manpower will be unable to provide adequate service and coverage due to a rapidly increasing county population. As indicated in Table 23, the departmental staff will require a 525 percent increase from eight full-time employees in 1973 to 50 employees by 1990. The most critical growth period will occur between 1974 and 1980, when the department, to meet the demand, would need to increase its present staff 24 full-time employees in conjunction with the county's 148.5 percent increase in population.

Converse County Sheriff's Department. In order to provide adequate service and coverage for an increasing population in the county, the sheriff's department would require a 159 percent increase from six full-time employees in 1973 to at least 15 employees by 1990 (Table 23). The departmental staff would be overextended by 1980 and would require seven additional staff members.

Municipal police departments

Tables 84 through 93 in Appendix C indicate the projected manpower that would be required for full-time policemen, office facilities,

and patrol vehicles for each municipal police department. Table 24 provides a summary of these needs for the region.

The needs for jail and correctional facilities have not been projected because of the lack of an acceptable criterion. The Law Enforcement Assistance Administration (U.S. Department of Justice) and local agencies could not provide or predict jail facility requirements per community population but indicated that existing facilities may require expansion if populations increase significantly. The capacity of jails is somewhat dependent on a number of crime factors.

Gillette Police Department. Table 84 in Appendix C provides a detailed assessment of projected police needs for Gillette. Basically, in order to provide an increasing city population with adequate police service and protection, the police department would need to grow 200 percent from 16 full-time policemen in 1973 to 47 officers by 1990. This substantial increase in staff size also would require 11 more patrol cars and an additional 1,250 square feet of office space.

By 1980, the existing police force would be overextended without an additional 14 full-time officers and five more patrol cars. Existing office facilities would be adequate until 1985, when an additional 800 square feet would be needed if the force were increased to meet the demand.

Douglas Police Department. A detailed assessment of projected police needs for Douglas is presented in Table 85 in Appendix C. Between 1973 and 1990, the police force would need to expand its existing staff size by 133 percent from six to 14 full-time policemen to meet the demand. To support this increase in manpower, the department would require an additional two patrol cars and 400 more square feet of office space.

Table 24

Summary of Deficits in Full Time Manpower, Office Space and Patrol Vehicles of Municipal Police Departments

Police Departments	1980 Deficits* Full Time Manpower	1980 Deficits* Office Sq.Ft.	1980 Deficits* Patrol Vehicles	1985 Deficits* Full Time Manpower	1985 Deficits* Office Sq.Ft.	1985 Deficits* Patrol Vehicles	1990 Deficits* Full Time Manpower	1990 Deficits* Office Sq.Ft.	1990 Deficits* Patrol Vehicles
Gillette	14	-	5	27	800	9	31	1,250	11
Douglas	5	200	1	6	300	1	7	400	2
Glenrock	2	300	1	3	400	2	3	400	2
Buffalo	3	770	1	3	770	1	3	770	1
Sheridan	2	-	1	2	-	1	2	-	1
Casper	21	-	10	23	-	10	25	-	10
Mills	2	300	-	2	300	-	2	300	-
Newcastle	0	200	-	0	200	-	0	200	-
Sundance	1	-	-	1	-	-	1	-	-
Lusk	-	-	-	-	-	-	-	-	-
Totals	50	1,770	19	67	2,770	24	74	3,320	27

*Deficits equal projected demands minus existing (1973) levels.

In order to accommodate the city's largest population increase between 1974 and 1980, the police department would need to double its existing full-time officer staff and acquire one more patrol car and an additional 200 square feet of office space.

Glenrock Police Department. As indicated in Table 86 in Appendix C, the department would need an additional three full-time policemen, two patrol cars and 400 square feet of office space by 1990 to meet the demand. The most substantial demand increases occur between 1974 and 1980, when the department would require an additional two full-time officers, 300 square feet of office space, and a patrol car.

Buffalo, Sheridan, and Casper Police Departments. The needs of these three departments to meet projected demands are indicated in Appendix C (Tables 87 through 89). By 1980, Buffalo would lack three full-time policemen, one patrol vehicle, and adequate office space; Sheridan would require an increase of two officers and one patrol vehicle; and Casper would lack 21 policemen and ten vehicles. If 1980 demand levels are met, Sheridan and Buffalo police departments would require no additional increases between 1980 and 1990. However, by 1990, Casper would need to increase its 1980 manpower demand level by four full-time officers.

Mills, Lusk, Newcastle, and Sundance Police Departments. Appendix C (Tables 90 through 93) describes the needs of these departments. At current levels, Newcastle, Lusk, and Sundance would have an adequate number of policemen and patrol vehicles to meet projected demands in the 1980 to 1990 period.

Municipal police department summary. Table 24 provides a summary of projected needs to meet the demand for 1980, 1985, and 1990. The major deficits occur between now and 1980 when a total of 50 officers, 1,770 square feet

of office space and 19 vehicles would be required to meet the demand on these departments by an expanded population.

Crime levels

In the description of the existing environment section of this report, the current levels of crime incidence are fully described for each county in the region. However, crime is a social problem that is not only difficult but nearly impossible to project in the future, especially in areas which will realize large immigration and rapid population increases. The Federal Bureau of Investigation (FBI) in its latest Uniform Crime Report states that factors which cause crime are many and vary from place to place. The FBI cautions against comparing statistical information of individual communities solely based on a similarity in their population counts.

Population is only one of many factors which must be considered. Some of the conditions or crime factors which affect the volume and type of crime that occurs from place to place are briefly outlined as follows (FBI 1973, p. vii):

--Density and size of the community population and metropolitan area of which it is a part.

--Composition of the population with reference particularly to age, sex and race.

--Economic status and morals of the population.

--Stability of population, including commuters, seasonal and other transient types.

--Climate, including seasonal weather conditions.

--Education, recreational and religious characteristics.

--Effective strength of the police force.

--Standards of appointments to the local police force.

--Policies of the prosecuting officials.

--Attitudes and policies of the courts and corrections.

--Relationships and attitudes of law enforcement and the community.

--Administrative and investigative efficiency of law enforcement.

--Including degree of adherence to crime reporting standards.

--Organization and cooperation of adjoining and overlapping police jurisdictions.

Since there is no way of predicting the socio-economic and personality profiles of incoming populations in the 1974-1990 time frame, the levels and types of crime incidence will remain largely unknown. Thus, the crime rate will change to indeterminable new levels, and this potential change in crime incidence will be an impact on the region as a whole.

Law enforcement agencies in Campbell and Converse Counties will require the largest increases in full-time staff sizes, facilities, and police vehicles. If the projected needs of these agencies are not met, the counties and local communities would not have adequate police services and proper coverage. While the presence of more police officers does not necessarily prevent crime or any increases, police officers are needed to arrest crime. Thus, a law enforcement agency with significantly large shortages in manpower may not be able to adequately respond to and investigate incidences as they occur. Under these conditions, increasing crime rates could impact a wider portion of the population.

Fire protection

From the National Fire Underwriters the recommended fire department strength of a city is based on the individual town's required fire flow. Estimated fire flow is based on a rather complicated formula involving a town's building composition and size. The number and location of fire houses is dependent on the distribution and shape of a town. In the absence of ability

to predict a growing town's building composition, Table 94 (Appendix C) provides a means of estimating fire flow on the basis of population. Once fire flow is estimated, Table 95 (Appendix C) can be used to establish the equipment necessary for the fire department.

Table 44, Appendix C, projects urban population increases for the Cities of Douglas and Gillette. Based on these forecasts, the impact and deficiency of existing facilities can be evaluated.

Douglas is projected for rather dramatic population increases by 1980 and 1990 that will increase its fire flow requirements from its presently less than 2,000 gpm (gallons per minute) to 2,500 gpm by 1980. Existing pumping units fail to meet this higher fire flow requirement and leave a deficiency of 1,500 gpm. Twenty volunteer firemen appear inadequate to meet a larger town's needs.

Gillette, even more than Douglas, is faced with tremendous population growth which will increase its existing fire flow requirements of 2,500 gpm to about 4,000 gpm by 1980 and about 5,000 gpm by 1990. Their present pumper truck capacity is already deficient by 750 gpm. By 1980, it is estimated that the community will need two pumper trucks with 2,250 gpm combined capacity and a ladder truck. By 1990, an additional pumper of 1,000 gpm capacity will be needed, plus another ladder truck. An additional fire house and full-time fire crew will likely be required.

Summary

Table 25 summarizes the estimated fire flow requirements of Douglas and Gillette.

Table 25

Fire Flow Requirements for Douglas and Gillette

	1974	1980		1985		1990	
Town	Capacity	Estimated Need	Deficiency	Estimated Need	Deficiency	Estimated Need	Deficiency
Douglas	1,000 gpm	2,500	-1,500	2,500	-1,500	2,500	-1,500
Gillette	1,750 gpm	4,000	-2,250	4,500	-2,750	5,000	-3,250

The net impact of having deficiencies of pumping capacity by these communities is that more damage could be sustained to burning buildings because of an inability to pump enough water onto larger fires. In the case of simultaneous fires in different parts of the city, the fire department may be spread too thin to provide adequate protection at either fire. The probability of larger and more damaging fires is thus increased. Potential loss of human life due to fire is also increased.

Water and sewer facilities

Nearly 80 percent of the growth induced by coal and other industrial development will occur in Campbell and Converse Counties and principally in the Cities of Gillette and Douglas; additional population will impact the capacity of the present water and sewer facilities.

Water

Gillette. Current and estimated water demands (Table 26) range from 1.3 million gallons per day (gpd) in 1970 to an anticipated 3.2 million gpd by 1980 and 5.0 million gpd by 1990[1] The water supply will be more than

[1] Wyoming State Engineer's office uses 180 gallons per day for per capita daily water usage as its standard for planning. Intermountain Planners and Wirth-Berger Associates (IPWBA), Ch. II, B.

6.1 million gpd by 1990 which will be more than sufficient to meet predicted 1990 demand (Intermountain Planners and Wirth-Berger Associates (IPWBA), Ch. IV). On the other hand, if the city's contract with the company building a power plant and a coal gasification plant to supply 3,500 acre-feet per year beginning in 1977 is not realized, the water supply will reach capacity between 1975 and 1980 (IPWBA, Ch. IV). The water treatment facility presently is inadequate to process a peak day demand for water.[1] The capacity of the water treatment plant is 2.2 million gpd and was 1.5 million gpd below the greatest level of service in 1970 and will be 7.0 million gpd and 12.2 million gpd below recommended capacity by 1980 and 1990, respectively.[2] The water distribution system is fully utilized at present; however, the distribution system will be insufficient by 1980 and 1990 by 6.5 million gpd and 10.8 million gpd ,respectively. The added population to the city of Gillette will place such water demands on existing facilities that expansion of the physical plant would be required by 1980 and 1990.

Douglas. Current and estimated water demand (Table 26) range from 0.5 million gpd in 1970 to an anticipated 1.1 million gpd by 1980 and 1.3 million gpd by 1990. The water supply will be over 3.0 million gpd by 1990 which will be more than sufficient to meet predicted 1990 demand. The capacity of the water treatment plant is 1.4 million gpd which is presently fully utilized and will be 1.7 million gpd and 2.2 million gpd below projected service levels by 1980 and 1990, respectively. The water distribution system is

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[1]Peak water usage is generally 2.5 times the average daily use or 450 gpd per capita. IPWBA, Ch. II, B.

[2]Water treatment plants should be able to process a peak day's usage plus 15% excess capacity. IPWBA, Ch. II, B.

		1970	1980	1990
WATER TREATMENT*				
Gillette:	Demand**	3,700,000 gpd##	9,200,000 gpd	14,500,000 gpd
	Present Capacity***	2,200,000 gpd	2,200,000 gpd	2,200,000 gpd
	Capacity Excess (+)# or Deficit (-)	- 1,500,000 gpd	-7,000,000 gpd	-12,200,000 gpd
Douglas:	Demand**	1,400,000 gpd	3,100,000 gpd	3,600,000 gpd
	Present Capacity***	1,400,000 gpd	1,400,000 gpd	1,400,000 gpd
	Capacity Excess (+)# or Deficit (-)	0 gpd	-1,700,000 gpd	-2,200,000 gpd
WATER DISTRIBUTION				
Gillette:	Demand**	3,700,000 gpd	9,200,000 gpd	14,500,000 gpd
	Present Capacity***	3,700,000 gpd	3,700,000 gpd	3,700,000 gpd
	Capacity Excess (+)# or Deficit (-)	0 gpd	-6,500,000 gpd	-10,800,000 gpd
Douglas:	Demand**	1,400,000 gpd	3,100,000 gpd	3,600,000 gpd
	Present Capacity***	1,400,000 gpd	1,400,000 gpd	1,400,000 gpd
	Capacity Excess (+)# or Deficit (-)	0 gpd	- 700,000 gpd	-2,200,000 gpd

*All calculations rounded to the nearest 100,000.

**Water treatment and distribution demand is 15 percent in excess of the product of peak water usage (450 gpd per capita) and total population. Intermountain Planners, Billings, Montana and Wirth-Berger Associates, Denver, Colorado (IPWBA) Powder River Basin Capital Facilities Study for the Wyoming Department of Economic Planning and Development (hereafter referred to as Capital Facilities Study), Chapter II-Public Facilities Demand and Cost, Section B - Demand for Services and Facilities, Water.

***IPWBA, Capital Facilities Study, Chapter I - Inventory of Public Facilities, Douglas and Gillette.

#Difference between demand and present capacity.

##gpd is abbreviated for gallons per day.

Table 26
Current and Projected Water Demands
for Douglas and Gillette, Wyoming 1970-1990

also fully utilized at present. The distribution system based on present levels will be insufficient to serve future demands by 0.7 million gpd in 1980 and 2.2 million gpd in 1990. Similar to Gillette, Douglas will need to expand existing facilities to satisfy the water demands of an increased population.

Sewer collection and treatment

Gillette. Sewer collection and treatment systems will need to expand to satisfy future populations from a 1970 demand of 1.2 million gpd to a 1980 demand of 3.0 million gpd and a 1990 demand of 4.7 million gpd[1] (Table 27). The present capacity of the sewer treatment plant is 1.4 million gpd. At present the sewer collection system is at two-thirds capacity. If no additions were made to the collection system, the system would reach capacity between 1975 and 1980. Assuming no expansion occurs, the collection system would be incapable of serving 1980 and 1990 projected demands by 1.2 million gpd and 2.9 million gpd, respectively. Although average daily usage in Gillette is less than the state average, Wyoming state standards were used for analytical purposes. The existing treatment plant is sufficient to more than meet current demand levels; however, population growth will place additional demands such that the facility will be deficient by 1.6 million gpd in 1980 and 3.3 million gpd in 1990. Present facilities must expand to meet the sewer demands of a growing population.

Douglas. Sewer collection and treatment systems will need to expand to satisfy the future populations from a 1970 demand of nearly 0.5 million gpd to a 1980 demand of 1.0 million gpd and a 1990 demand of 1.2 million gpd (Table 27). Capacity of the water treatment and collection system

[1]Maximum daily flow would be about 168 gallons per capita, IPWBA, Ch. II, B.

		1970	1980	1990
WASTE WATER COLLECTION*				
Gillette:	Demand**	1,200,000 gpd##	3,000,000 gpd	4,700,000 gpd
	Present Capacity***	1,800,000 gpd	1,800,000 gpd	1,800,000 gpd
	Capacity Excess (+)# or Deficit (-)	+ 600,000 gpd	-1,200,000 gpd	-2,900,000 gpd
Douglas:	Demand**	500,000 gpd	1,000,000 gpd	1,200,000 gpd
	Present Capacity***	500,000 gpd	500,000 gpd	500,000 gpd
	Capacity Excess (+)# or Deficit (-)	0 gpd	- 500,000 gpd	- 700,000 gpd
WASTE WATER TREATMENT*				
Gillette:	Demand**	1,200,000 gpd	3,000,000 gpd	4,700,000 gpd
	Present Capacity***	1,400,000 gpd	1,400,000 gpd	1,400,000 gpd
	Capacity Excess (+)# or Deficit (-)	+2,000,000 gpd	-1,600,000 gpd	-3,300,000 gpd
Douglas:	Demand**	500,000 gpd	1,000,000 gpd	1,200,000 gpd
	Present Capacity***	500,000 gpd	500,000 gpd	500,000 gpd
	Capacity Excess (+)# or Deficit (-)	0 gpd	- 500,000 gpd	- 700,000 gpd

*All calculations rounded to the nearest 100,000.
**Waste Water Collection and Demand is the product of the maximum expected daily flow (168 gallons per capita) and total population. Intermountain Planners, Billings, Montana and Wirth-Berger Associates, Denver, Colorado (IPWBA) Powder River Capital Facilities Study for the Wyoming Department of Economic Planning and Development (hereafter referred to as Capital Facilities Study), Chapter II - Public Facilities Demand and Cost, Section B-Demand for Services and Facilities, Sewer.
***IPWBA, Capital Facilities Study, Chapter I - Inventory of Public Facilities, Douglas and Gillette.
#Difference between demand and present capacity.
##gpd is abbreviated for gallons per day.

Table 27
Current and Projected Sewer Demands for
Douglas and Gillette

is about 0.5 million gpd. While current sewage demands are satisfied, the present systems are inadequate to accommodate anticipated increased demands. Both the present waste water collection and treatment facilities will be deficient by 0.5 million gpd by 1980 and 0.7 million gpd in 1990. Present facilities must expand to meet the sewer demands of a growing population.

Summary

If water and sewer facilities are not expanded in a timely fashion to meet the demands of an expanding population significant secondary impacts could occur. If water is not treated properly serious health hazards could develop. Use of a poor quality water could result in a higher incidence of disease and possibly to epidemics of major diseases.

Overuse of the sewage facilities could result in more sewage being dumped into stream channels, such as Donkey Creek and eventually into the North Platte River. This would lower water quality and impact fish and wildlife populations. The polluted water could also act as the source of diseases, especially if ground water aquifers become polluted.

Utilities

Although most utility companies contacted felt their system could adequately handle increased consumer demand from the projected population increases and could respond to consumer service requests in a timely fashion, exceptions were noted. One natural gas company was unsure as to its ability to provide service to new customers because its supplier advised them that quantities of fuel in addition to their present quota might not be forthcoming. The local distributor could add no further specifics to this warning.

The utility companies are experiencing long delays in the acquisition of certain construction materials. There is likely potential pipe

shortage and some major equipment items such as pole transformers are taking up to 50 weeks to acquire. The companies are planning and ordering supplies further in advance to resolve this problem.

The telephone company in Douglas felt it could handle new orders for telephone service unless the direction in which the town grew was to the north where adequate tie-in service was not available. Also, if a coal gasification plant were to locate near Douglas, service to some new residential areas could possibly be delayed up to six months regardless of where they located because of the massive number of new employees required for this type of plant.

Most of the utility companies would have to hire additional crews if faced with a very sudden increase in demand as in the case of Douglas and a coal gasification plant.

Other than the instances cited above, none of the utility companies expected that demand on their facilities would induce shortages of service or conditions that may curtail service (brownouts, rationing, etc.). Electrical shortages in this area are not likely. It is not possible to identify a point when saturation of their facilities might occur to require a cutback in service. Facility expansion is presently a continual process in this area and their ability to react to fluctuations appears good. As a rule, the companies are anticipating increased consumer demand due to sudden population increases and are planning and engineering the needed improvements.

Community attitudes and life styles

Community attitudes cannot be predicted with any accuracy. The multitude of economic, social, and psychological (among other) variables which come together in the unique combinations known as community attitudes are

difficult enough to assess at a given point in time. Following the introduction of a new element into the community system, attitude assessment becomes an impossible task.

The impact of development on prevailing life styles will depend upon the magnitude and speed of population growth, the degree to which public services can accommodate that growth, and the ability and desire of incoming persons to establish ties in the community.

In Campbell County the prevailing ranching lifestyle fell before the onslaught of a sudden population influx which could not be accommodated by existing public services. In addition, although many of the new residents did establish strong community ties, many did not. Faced with another period of rapid development, present difficulties in defining a new lifestyle will be aggravated. Efforts to provide for the needs of the last population influx have succeeded in reducing the severity of the present situation.

In Converse County, ranching remains the dominant lifestyle. However, with population increases expected to more than double the population between 1970 and 1980, ranching will lose much of its dominance. Economically, mineral related employment will gain dominance. While ranching may shift in economic importance, social importance will depend upon community preparedness. If public services are adequately and plentifully supplied, assimilation is far more likely to occur. Although the speed and magnitude of population growth suggests that assimilation will be incomplete, the ranching lifestyle will remain more visible than if amalgamation were to occur.

Since lifestyle impact is a direct function of population growth, of the six remaining counties in the area, only Johnson County should be strongly affected. With a projected 50 percent population increase between 1970 and 1980, Johnson County may be severely enough impacted to experience lifestyle stress.

CHAPTER VI

SIGNIFICANT MITIGATING MEASURES

This chapter summarizes authorities, both in law and regulation, that will mitigate possible adverse effects of coal and industrial development in the Eastern Powder River Coal Basin. Technological treatments available are discussed in Parts II through VII of this statement along with the consideration of specific actions.

Climate

Since potential weather modification is closely related to air quality standards and resource disturbance, more detailed information concerning mitigating measures are contained within these chapters. The utilization of emissions control equipment on vehicles, plant stacks, dust control measures and timely revegetation of mined lands will reduce particulate matter available to the atmosphere and reduce the effects on weather from alteration of the earth atmospheric energy balance.

Air Quality

The enforcement of all applicable federal and state laws and regulations concerning air quality standards for control of emissions will reduce the cumulative effects on air quality of regional development. These include:

1. Federal Clean Air Act, as amended in 1970;
2. National Ambient Air Quality Standards;
3. New Source Performance Standards (NSPS);
4. National Emission Standards for Hazardous Air Pollutants;
5. Wyoming Environmental Quality Act of 1973; and
6. Wyoming Ambient Air Quality Regulations.

Development and utilization of reliable emission control equipment on existing and new equipment, vehicles and plant stacks will reduce the cumulative amount of pollutants entering the regional atmosphere.

Air quality standards

National Ambient Air Quality Standards (NAAQS) for suspended particulate matter, sulfur oxides, nitrogen oxides, photochemical oxidants, carbon monoxide, and hydrocarbons were promulgated by the Environmental Protection Agency (EPA) on April 30, 1971, under provisions of the Clean Air Act, as amended in 1970. Table 1 lists these standards. It is the responsibility of the Wyoming Department of Environmental Quality to insure that these standards are attained and maintained. If the state does not carry out this responsibility, EPA must take action to enforce the standards. Primary standards are health related and, in most cases, must be achieved by July 1975. Secondary standards are welfare related (material, vegetation, visibility, etc.) and must be achieved as expeditiously as possible. In rural areas this may mean July 1975, whereas in urban areas it may mean well beyond July 1977.

Wyoming ambient air quality standards were promulgated in accordance with the Wyoming Environmental Quality Act of 1973. Under Article 2 of the Act the Wyoming Department of Environmental Quality, Air Quality Division, is empowered to enforce standards. Table 2 contains the Wyoming ambient air quality standards. Wyoming has also adopted emission regulations; these standards are shown in Table 3.

Any new fossil fuel-fired steam generators or modification to existing plants must conform to the New Source Performance Standards (NSPS). Table 4 lists these standards.

Table 1

National Ambient Air Quality Standards

Pollutant	Primary Standard	Secondary Standard
1. Sulfur Oxides	80 ug/m^3 (0.03 ppm) annual arith. mean 365 ug/m^3 (0.14 ppm) max. 24 hr. conc. not to be exceeded more than once a year.	1300 ug/m^3 (0.5 ppm) max. 3 hr. conc. not to be exceeded more than once a year.
2. Particulate Matter	75 ug/m^3 annual geom. mean 260 ug/m^3 max. 24 hr. conc. not to be exceeded more than once a year.	60 ug/m^3 annual geom. mean*, 150 ug/m^3 max. 24 hr. conc. not to be exceeded more than once a year.
3. Carbon Monoxide	10,000 ug/m^3 (9 ppm) max. 8 hr. conc. not to be exceeded more than once a year.	Same as primary.
	40,000 ug/m^3 (35 ppm) max. 1 hr. conc. not to be exceeded more than once a year.	Same as primary.
4. Photo Chemical Oxidants (corrected for NO_2 and SO_2 interference.	160 ug/m^3 (0.08 ppm) max. 1 hr. conc. not to be exceeded more than once a year.	Same as primary.
5. Hydrocarbons (corrected for CH_4)	160 ug/m^3 (0.24 ppm) max. 3 hr. conc. (6 to 9 a.m.) not to be exceeded more than once a year.	Same as primary.
6. Nitrogen Oxides (as Nitrogen Dioxide)	100 ug/m^3 (0.05 ppm) annual arith. mean.	Same as primary.

*To be used as guide in assessing State Implementation Plans.

Table 2

Wyoming Ambient Air Quality Standards

Pollutant	Standard						
	Annual	Month	24-hour	8-hour	3-hour	1-hour	1/2 hour
Particulate, ug/m^3	60 G.M.	-	150**	-	-	-	-
, COH/1000 feet	0.4	-	-	-	-	-	-
SO_2, ug/m^3	60	-	260**	-	1.300**	-	-
, sulfation mg $SO_3/100\ cm^2/day$	0.25	0.50	-	-	-	-	-
CO, mg/m^3	-	-	-	10**	-	40**	-
NO_x, ug/m^3	100 A.M.	-	-	-	-	-	-
HC, ug/m^3	-	-	-	-	160**	-	-
Oxidants, ug/m^3	-	-	-	-	-	160**	-
HF, total, ppb	-	-	1	-	-	-	-
HF, forage - ppmw	25	-	-	-	-	-	-
HF, gaseous - ug/cm^2	-	0.3	-	-	-	-	-
H_2S, ug/m^3	-	-	-	-	-	-	40 *twice/ 5 days 70 *twice/ year

*Not to be exceeded more than

**Not to be exceeded more than once per year

Table 3

Wyoming Emission Standards

A. Fuel Combustion - Particulate Matter

10^6 Btu/hr. Fuel Heat Input*	# Particulate/10^6 Btu Existing Source	New Source**
10	0.6	0.10
10,000	0.18	0.10

B. Fuel Combustion - NO_x

Fuel Fired	# NO_x/10^6 Btu Existing Source	New Source**
Gas	0.23	0.2
Oil	0.46	0.3

C. Visible Emissions

Existing Source	40 percent opacity
New Source**	20 percent opacity

*Interpolate between values
**After February 22, 1972

Table 4

NSPS for Steam Generators

	Allowable Emissions Fuel-Fired Coal	Oil	Gas
Particulate, #/10^6 Btu	0.10	0.10	0.10
Particulate, opacity	20%	20%	20%
Sulfur dioxide, #/10^6 Btu	1.20	0.80	--
Nitrogen oxides, #/10^6 Btu	0.70	0.30	0.20

Water Quality and Supply

National standards to restore and maintain the chemical, physical and biological integrity of the nation's waters were promulgated by the Federal Water Pollution Control Act (FWPCA) as amended in 1972, and as it may be hereafter amended.

Wyoming water quality standards were issued in accordance with the Wyoming Environmental Quality Act of 1973. Under Article 3 of the Act, the Wyoming Department of Environmental Quality, Water Quality Division, is empowered to enforce these water quality standards. Important prescribed standards include those which specify maximum short-term and long-term concentrations of pollution, minimum permissible concentrations of dissolved oxygen and other matter, and the permissible temperatures of the waters of the state. Effluent standards and limitations specifying the maximum amounts of pollution and waste which may be discharged into state waters are described. Other health and water quality standards pursuant to section 402(b) of the FWPCA, as amended in 1972, are described as well.

The enforcement of all applicable federal and state laws and regulations concerning water quality standards will reduce the cumulative effects of regional development on water quality. These include:

1. Federal Water Pollution Control Act, as amended in 1972, and as it may be hereafter amended;
2. Wyoming Environmental Quality Act of 1973; and
3. Water Quality Standard for Wyoming, Wyoming Department of Health and Social Services, State of Wyoming, June 28, 1973.

Water supplies

Wyoming water law requires water-right filings for water impoundments and for the general utilization of water from ground- or surface-water sources. If the mining activity interfers with existing ground- or surface-water rights, it may be required that water be provided to satisfy these rights.

Provisions under Wyoming water law make it possible to change the location of a well, a reservoir or irrigated lands that are affected by activities such as mining. This would prevent the loss of these facilities and of irrigated lands, and in many instances would reduce the impact of the mining activity.

The appropriation of and supervision and distribution of ground and surface water is under control of the office of State Engineer and the Board of Control.

Monitoring programs

Monitoring programs are being established by companies planning to mine coal. A number of the monitoring programs are being planned in consultation with the Water Resources Division of the U.S. Geological Survey. The programs consist of establishing observation wells to determine water level fluctuations in the coal and the overlying overburden in the mine lease areas. Water samples are being collected to determine the chemical quality of the water and to serve as a basis for detecting changes in water quality after mining begins. As mining of coal progresses, additional observation wells will be established in or near backfill areas to monitor for leaching of toxic materials from the backfill and movement of the water from the backfill areas.

Resource Disturbance

Federal

Significant disturbances to the natural and human environment are associated with surface mining and railroad, transmission, pipeline and road construction. Unless measures to mitigate impacts are initiated timely after disturbance occurs, productive capacity of the affected areas may be lowered and other adverse effects realized. Listed below are some of the laws and regulations which grant the Secretaries of Interior and Agriculture and the Commissioner of the Interstate Commerce Commission authority to impose measures that will mitigate adverse impacts on the natural and human environment:

1. Mineral Leasing Act (41 Stat. 437 as amended; 30 U.S.C. 181 et seq);
2. Mineral Leasing Act for Acquired Lands (61 Stat. 913; 30 U.S.C. 351-359);
3. Multiple Use-Sustained Yield Act of 1960 (74 Stat. 215; 16 U.S.C. 528-531);
4. Bankhead-Jones Farm Tenant Act of July 22, 1937 (50 Stat. 525; 7 U.S.C. 1010-1012);
5. Interstate Commerce Act (49 Stat. 543; 49 U.S.C. 1(18));
6. Title 43 CFR Parts 23 and 3500;
7. Title 43 CFR Subpart 3501;
8. Title 30 CFR Part 211; and
9. Title 36 CFR Part 213.

Mitigating measures with respect to development of coal are found in the Mineral Leasing Act of 1920, as amended. The lessee has the obligation to report quarterly on the amount and character of extracted leased coal, make quarterly royalty and

annual lease payments, and protect and rehabilitate the surface. The Mineral Leasing Act for Acquired Lands authorized the leasing of mineral deposits, with the consent of the agency having jurisdiction over the lands, in lands acquired by the United States to which the "mineral leasing laws" have not been extended. In addition, the mine operator is subject to the supervision and administration of the Department of Interior through the Geological Survey in conjunction with the agency having administrative jurisdiction of the surface. The lessee must comply with CFR Part 211, Coal Mining Operating Regulations. These coal operating regulations were revised and published in the Federal Register as proposed rules on April 30, 1973. These regulations will govern operations for discovery, testing, development, mining and preparation of coal under leases, licenses and permits issued on public domain and acquired lands pursuant to the regulations in 43 CFR Group 3500. The purpose of the regulations in Part 211 is to promote orderly and efficient operations and production practices without waste or avoidable loss of coal or other mineral bearing formation; to encourage maximum recovery and use of coal resources; to promote operating practices which will avoid, minimize, or correct damage to the environment, including land, water, and air, and avoid, minimize, or correct hazards to public health and safety; and to obtain a proper record of all coal produced.

Bonding

Title 43 Code of Federal Regulations, Part 23.9 states: "Upon approval of an exploration plan or mining plan, the operator shall be required to file a suitable performance bond of not less than $2,000. . . . The Bond shall be in an amount sufficient to satisfy the reclamation requirements of an approved exploration or mining plan, or an approved partial or

supplemental plan. In determining the amount of the bond, consideration shall be given to the character and nature of the reclamation requirements and estimated costs of reclamation in the event that the operator forfeits his performance bond."

Deposits of cash or negotiable bonds may be used in lieu of surety bonds. An operator may file a nationwide or statewide lease surety bond with the Bureau of Land Management to cover reclamation requirements under more than one lease if its terms and conditions are sufficient to comply with the regulations in 43 CFR Part 23. The amount of bond required to cover each lease is established by the BLM district manager after consultation with the Geological Survey mining supervisor, and when appropriate with other land management agencies if involved.

43 CFR 23.9 was issued January 18, 1969, and its requirements have been incorporated in all coal leases issued by BLM since that date.

Most coal leases issued by BLM prior to January 1969 were issued on a lease form similar to the current coal lease form (Form 3130-1), which states in Sec. 2, that the lessee agrees "to maintain the bond furnished upon the issuance of this lease, which bond is conditioned upon compliance with all provisions of the lease, and to increase the amount or furnish such other bond as may be required." A nationwide or statewide bond may also be used in lieu of the bond required by this section.

Such a bond covers compliance with Sec. 5 of the lease, titled "protection of the surface, natural resources and improvements." The amount of bond required under either provision may be adjusted to cover the estimated cost of compliance, at any given time, with the lease terms and terms of any approved mining and reclamation plans.

Wyoming

Wyoming's Environmental Quality Act of 1973 created the Department of Environmental Quality and vested in that agency broad powers to oversee and enforce mined land restoration and reclamation in the state. In addition to establishing rules and regulations DEQ also grants permits and licenses to mine or explore for minerals; invokes penalties for non compliance; requires and collects performance bonds; and can reclaim mined land if bonds are forfeited. Written consent or waiver by the surface owner is required before a mining permit can be granted.

Proposed land quality regulations are in the public hearing stage and should soon be issued in final form. However, under terms of the Act, minimum reclamation standards require restoration of land to equal or higher value; revegetation of mined lands; stockpiling and reuse of topsoil; and prevention of erosion, land slides, sedimentation and water pollution. Upon conclusion of reclamation, up to 75 percent of the bond may be returned to the operator. The remaining 25 percent, and not less than $10,000, is held for five years to insure proper revegetation. This also may be returned on consent of the landowner and the DEQ.

Violation of the Act or regulations can result in penalties up to $10,000 per day for non-willful violations. The penalty for willful violations is up to $25,000 per day and/or up to a year in prison. Penalty limits double for second offenses.

Surface protection and rehabilitation

Each mining operation, road, pipeline, powerline, railroad or other action that would cause surface disturbance is unique, having different construction and operating requirements. Surface disturbing activities vary from casual occupation of the surface such as off-road vehicle use to complete disruption of the land surface and underlying strata. In addition, these activities normally occur through time and over areas with differences in climate, topography, soils and vegetation.

Preplanning--land use objectives

In view of all the variations that will be encountered, preplanning is necessary to assure successful surface protection and land rehabilitation. A determination must be made in the preplanning stage of the use to which land might be committed after mining and reclamation, and consideration given to the site suitability and capability to respond to rehabilitation.

Land use objectives should be selected and decided upon before mining. Objectives should be compatible with controlling physical conditions such as climate, soils and local topography and must be realistically attainable.

In order to preplan rehabilitation and determine land use objectives, an assessment is needed of overburden, its physical and chemical characteristics. Topography, hydrology, mining methods and equipment, access roads, road grades, transportation systems, pit limits, stripping ratio of overburden to coal, production rates, and bench heights must also be considered.

In general, the mining and reclamation plan filed with the U.S. Geological Survey, in conjunction with federal regulations, state laws, and the coal lease terms, requires actions to mitigate adverse effects of surface mining. The restored landform will be determined by consultations among the operator, the agency having jurisdiction over the surface, the Wyoming Department of Environmental Quality and the U.S. Geological Survey. Such consultations will be frequent enough so as not to unnecessarily impede progress of mining or reclamation.

Topography

Topography of the existing land will be studied in view of the mining or construction activities that are expected to take place. The topography that would follow mining or construction will be predetermined in detail in accordance with the rehabilitation capabilities and land use objectives. Prior to mining, landscape models will be designed to depict a suitable topography based on the amount of overburden, mining methods and land use objectives.

The reshaping of disturbed areas should conform to adjacent terrain and the topography should be reshaped to achieve the best ecological conditions, meet proper drainage and hydrologic conditions and present a pleasing landscape. Unusual, objectionable or unnatural landforms will be avoided.

A major consideration determining topography of the mined areas throughout the region is the overburden to coal ratio. The thick coalbeds of

the area are overlain by thin overburden. Restoration of the land surface to its former elevations is unlikely due to the existing coal to overburden ratios.

The National Academy of Sciences, Study Committee on the Potential for Rehabilitating Lands Surface Mined for Coal in the Western United States, considered that the placement of excavated overburden should offer optimum conditions for land stability, drainage control and revegetation. It was stated that maximum vegetative stability could not be attained on slopes steeper than 33 percent (3:1) and that optimum vegetative stability would require slopes of less than 20 percent (5:1). Various land uses such as wildlife habitat, building sites or farming may tolerate a range of slopes.

Limits on machinery operation and erosion potential are considered essential to the rehabilitation success and maintenance of surface land values. (U.S.D.A. Soil Conservation Service 1971). Some other limitations of various slope classes are listed below:

Level to gentle slopes 0-20 percent (level to 5:1) can be reclaimed for irrigated cropland, urbanization, grazing, wildlife habitat, and recreation, including water impoundments. Various land use values may be limited to some extent within this slope class. Erosion hazards and influence on revegetation is minimal. Mechanical treatment and seeding are not limited by steepness of slope.

Moderately steep slopes 20-33 percent (5:1-3:1) can be reclaimed for grazing, woodland, orchards, recreation, and wildlife habitat, including water impoundments. Light agricultural machinery can be used for rehabilitation.

Moderate erosion hazards are experienced. Revegetation can be successfully established and maintained.

Quite steep slopes 33 percent plus (3:1 and steeper) have limited use potential. Grazing may be permitted and suitable wildlife habitat may be established. Use of machinery is restricted. Revegetation of these slopes may be difficult and severe erosion hazards persist, unless stabilizing structures are used.

Mining equipment used for overburden removal is selected after consideration of type of overburden, thickness of overburden, topography, reclamation requirements and coal production. The shaping of the topography will depend on the types of mining equipment used. The types of equipment contemplated for overburden removal in the region include draglines, power shovels and truck, dozer and scraper, and wheel excavators. Draglines and wheel excavators leave a series of peaked spoil banks or ridges in their wake that require considerable slope reduction and final shaping to achieve an acceptable topography. Scrapers and trucks can discard overburden spoil to a planned grade that requires only minor shaping and grading. Scrapers and truck methods of overburden removal are generally used only where limited amounts of overburden are present.

The placement and final grading of overburden should be accomplished in such a manner that a natural and compatible topography can be achieved. The land form will provide conditions conducive to land surface stability, adequate drainage and surface conditions capable of supporting the desired vegetation. No spoil or cut slope should exceed a 33 percent (3:1) grade after rehabilitation.

Unreclaimed highwall areas may be unsightly and can be a safety hazard to humans, wildlife, and livestock and may limit land use. High walls will be reduced to a slope no steeper than 3:1 during final cut. Erosion control structures such as terraces, water breaks, or other suitable structures may be necessary.

If highwall areas of steeper slopes are necessary to maintain recreation lakes or ponds, protective fencing will be installed above the slope and the approach to the water should not exceed a 3:1 slope.

Drainage

During reshaping and final grading, provision will be made for adequate drainage through a reestablishment of drainage systems that are compatible with the natural drainage systems of adjoining lands.

Accumulation and concentration of salts, toxic elements, or other harmful materials by evaporation of surface waters should not be permitted. These impoundments should be removed if not installed to control pollution of streams or land surface.

Shaping of spoils to manage water is an important aspect of rehabilitation. Where operations could result in acid or saline drainage or sediment damage to adjoining lands, provision will be made for water impoundments. Runoff from spoil areas should be prevented from causing siltation, erosion or other damage to streams or natural water courses. When desirable, downstream erosion control and flood control structures will be required prior to excavations. All water impoundments should be properly designed and constructed for that purpose with suitable outlet structures and spillways installed if appropriate.

Surface hydrology is affected materially by the surface of spoil areas. Spoil surface design is fundamental in intercepting and impeding runoff flows. Runoff from precipitation on spoils is reduced by a roughened surface or increased porosity of spoil materials. Surface manipulation may be used to retard runoff erosion and relieve compaction due to heavy machinery. Terracing, pitting, ditching, listing, deep chiseling, and discing or leaving a roughened surface may be required to reduce excessive runoff, increase soil moisture, and reduce erosion. These practices should not be performed on saline soils since accumulation and concentration of salts would create alkali spots in surface pits and hinder revegetation.

Spoil materials characteristics

Spoils left by mining are mostly a mixture of freshly broken sandstones and shale, and some soil. These spoil materials weather and break into particles that are subject to erosion. Active erosion begins as soon as mining operations expose the spoil materials and occurs most rapidly at the surface.

Overburden materials left as spoils following mining were studied by the USDA Northern Great Plains Research Center. Results showed that the physiochemical properties of materials left as spoils provided a poor environment for vegetative growth.

The various layers of overburden may become mixed upon removal from the mine area. Some of these layers may contain toxic concentrations of elements such as boron, arsenic, and selenium. Analysis of the surface soils and overburden should be made and examined for concentration of toxic materials in relation to stratigraphic occurrence. Mining operations will be planned to provide for the segregation of spoil materials toxic to humans, animals, and vegetation. All exposed coalbeds should be covered by at least three feet of soil material to prevent coal fires and aid revegetation. Waste coal and toxic material should be buried in spoil so as not to inhibit revegetation efforts or be a potential source of pollution to ground or surface waters.

Spoil and surface soil textures influence the amount of moisture available for plant growth. Materials composed largely of sandy material exhibit good aeration and percolation properties but are apt to be droughty. Clay materials compact easily from machinery operations and crust during dry periods. Loams and silty material usually have enough fine materials to hold moisture. The textures of the spoil and soil materials are important to the types of vegetation to be established and the success of revegetation.

Unweathered and unleached spoil materials may contain significant amounts of saline or less likely acid materials which if used as surface material would be a source of pollution to adjoining lands and streams and incapable of supporting significant amounts of plant growth. Excessively acid or alkaline surface or overburden materials will not be used as surface material.

Excessive acid or alkaline surface material that contains toxic or deleterious materials and infertile materials should be buried at a depth that will not reduce reestablishment of adequate vegetative cover. The surface overburden materials should have favorable pH's capable of supporting plant growth.

pH Range 6.0-8.5: This soil class will support a wide variety of climatically adapted plants.

pH greater than 8.5: Plant establishment will be difficult.

pH less than 6.0: Plant establishment will be difficult.

Topsoil

Vegetative establishment cannot succeed without a proper medium for plant growth. The soil-forming process is slow in semiarid climates and topsoil is thin on most hilltops and steep hillsides. However, drainages may contain several feet of alluvial materials.

Beauchamp (1973) considered that topsoil should be used if it is not excessively alkaline or acid since it may contain minerals not present in the overburden spoil. The National Academy of Science Study Committee on the Potential for Rehabilitating Lands Surface Mined for Coal in the Western United States considered that special attention must be given to saving any soil of acceptable quality that exists on a mined site. It was also considered that the values to be derived from adding topsoil are often decreased by stockpiling the soil since one advantage of spreading topsoil is the transplanting of live seeds and plants, especially rhizomatous species.

The entire topsoil structure to the total depth of suitable surface materials will be stripped from all areas where surface disturbance or

coverage by spoil piles is planned and stockpiled for later use or moved directly to a reshaped and prepared rehabilitation area. Topsoil stockpiles should be located in such a manner and place that mixing with subsurface materials will be prevented. If possible, topsoil should be returned immediately to spoil areas that have been graded and shaped to the desired landform and topography since live seeds, rhizomes and soil microorganisms are lost if soil is stockpiled for any length of time. Stripping and respreading of topsoil will be considered as part of the seedbed preparation and will be timed to coincide with this phase of rehabilitation. Reinoculation of stored topsoil may be accomplished by addition of manure or mixing with fresh topsoil.

Mulch

Vegetation can be established only with difficulty on soils being rapidly eroded. Topsoil is characteristically loose, friable and susceptible to both wind and water erosion. Mulches increase infiltration, reduce erosion, soil movement, evaporation and materially enhance revegetation potential especially where poor soil texture conditions exist. Mulches are effective in areas where annual precipitation is between 9 and 14 inches. (National Academy of Science 1974).

Mulch composed of plant residues or other suitable materials will be required as part of seedbed preparation. Acceptable mulching materials are grass, hay, manure, and small grain straw. The mulch material should be applied at two tons or more per acre and anchored by discing, special mulch

machine, or a Colter type machine to a depth of two inches. Other types of mulch material such as straw mat, fine wood fiber, excelsior mesh, plastic mesh, wood chips, gravel and jute mesh can be used. The type, rate, and anchorage of mulch will be specified.

Seeding

Rehabilitation of mixed grass prairie sites has not been difficult when proper seeding has been used. The time of planting is critical for dryland seeding. In the Northern Great Plains area, early spring or late fall seedings are the most reliable. Planting of cool-season grasses that are capable of germinating under very cold conditions and can aestivate when soil moisture is depleted is desirable. (Hodder 1970).

Most land reclamation seeding will take place under dryland conditions unless irrigation water is available. Snow or spring rains provide moisture for germination, initial growth, and establishment. New seedlings, when producing rudimentary root systems and a primary leaf cannot tolerate extended drought. Supplying irrigation water will be required when drought conditions threaten seed germination and plant survival. A suitable water supply will be made available in anticipation of these periodic conditions.

The dryland farming practice of summer fallowing prior to seeding may be required to allow for an adequate accumulation of soil moisture reserves to assure successful vegetation establishment. If such a practice is used adequate erosion controls on unprotected spoil areas (such as surface manipulation and mulching) will be provided.

The species selected for planting must be adapted to local soil and climatic conditions. Native species may be desirable since they have been selected through the process of natural selection and are adapted to local climatic and soil conditions. The unavailability of seed and unreliability of seed sources limit the use of native species.

Hodder 1970, considered that some introduced species possessed superior qualities essential for rapid establishment. Many species of introduced grasses and legumes have been used successfully for stabilizing road cuts and arid ranges (National Academy of Science 1974).

Trees and shrubs may be used on lands being reclaimed for recreation or wildlife habitat. Most woody species should be planted from stock rather than seed for best success. Hodder (1973) lists several innovations or techniques being tested for tree and shrub establishment such as condensation traps, supplemental root transplanting and tubelings. Sites selected for woody species should be capable of supporting this type of vegetation. Some shrubs such as big sagebrush and fourwing saltbush have been seeded successfully. A mixture of native shrubs, trees, grasses, forbs, and introduced species of vegetation may be required on suitable areas where soils and topographic conditions are varied. This mixture would provide a greater opportunity for diverse land uses such as recreation, livestock grazing, and wildlife habitat.

Several seeding methods are available for planting grasses and legumes. Drilling the seed by readily available farm equipment has proven to be the most successful method of planting. Seed distribution and coverage is assured and uniform. Broadcast seeding is satisfactory for small or relatively inaccessible areas. Broadcast seed should be covered by raking, harrowing, or other means.

Rehabilitation of mined land is usually performed under less than ideal farming conditions. Standard seeding rates are usually doubled or increased significantly to allow for seed and seedling mortality due to adverse conditions present on mined lands and other rehabilitation areas. Revegetation failures will occur. The operator will be required to attempt revegetation as many times as necessary to achieve reasonable success.

Fertilizing

Maintenance of vegetation on disturbed areas depends to a large extent upon soil development. Applying manure, sewage sludge, or other organic material will materially enhance the soils capability to supply plants with water and nutrients. Commercial fertilizers are convenient to handle and easy to obtain. The effectiveness of nitrogen fertilizers, however, is dependent on the amount of moisture available. It is generally considered that annual precipitation should be at least 10 to 12 inches to receive benefit from commercial fertilizer on rehabilitation areas. The type of fertilizer and rate of application should be specified when appropriate.

Equipment use

A considerable amount of activity by all types of equipment will occur during construction and mining. Wheeled and tracked equipment will be used in a manner that will minimize surface damages.

Excess disturbance of drainages and high erosion hazard areas will be avoided. During muddy or wet conditions, use of heavy equipment will generally be confined to the construction or mining site.

Rights-of-way, roads

Temporary roads to construction sites or similar developments will be rehabilitated when abandoned. Spoil banks, windrowed soils, debris, and fill material will be replaced in the roadbed and graded to conform to the topography. Cut slopes will be reduced as the fill permits. Closed roads will conform to existing terrain, and be waterbarred and conditioned for revegetation upon abandonment.

Existing roads and trails will be used whenever possible for access purposes. Construction of roads on steep hillsides will be avoided where alternate routes provide adequate access. Ridge tops or level areas usually offer the best access route along with minimizing surface impacts. Drainage will not be blocked by roadfills.

Permanent service roads will be constructed to acceptable standards and maintained in a good condition for vehicle use. Adequate water drainage will be provided to minimize erosion. Erosion of borrow pits by runoff water will be prevented by diverting water at frequent intervals. This may involve construction of waterbreaks, culverts, broadbased drainage dips, graveling or other methods.

Rights-of-way will not be located across high erosion hazard areas or areas of unique values. Construction will be conducted in a manner that will minimize soil erosion. Rights-of-way will not be used for "short cut" trails or roads unless properly constructed for such purposes.

Deep vertical cuts and long fill slopes of clinker pits, roads, pipelines or other construction sites will be graded by reducing slopes, backfilling to conform to the adjacent terrain.

To prevent erosion, waterbreaks, terraces, or diversion ditches should be installed and the water spilled onto areas relatively resistant to erosion.

Waste disposal

Release of waste water containing injurious or deleterious materials will be avoided. Disposal system for solid and liquid wastes will be designed so as not to cause damage to adjoining lands or drainages. Solid waste should be buried or disposed of between impervious overburden layers to prevent its reaching surface water courses or aquifers. Liquid disposal pits containing toxic or deleterious materials will be lined or constructed so as to avoid downward percolation and contamination of ground water aquifers.

Mineral protection

Oil and gas leases are in effect for much of the area. Priorities for mining or drilling for oil and gas on public lands are established by the Conservation Division of the U.S. Geological Survey. Mining operations approaching wells or bore holes that may liberate oil, gas, water, or other fluid substances must be approved in accordance with 30 CFR 211.17 and 30 CFR 211.63. Impacts on oil and gas areas can be mitigated largely by agreements among operators where significant impact on oil well siting or pipeline location arises. In extreme instances of conflict, technology is adequate through directional drilling, drainage practice, recovery of wells lost, pipeline and flowline relocation, pillar recovery, and mining method to adequately mitigate impacts which might arise.

Impacts on uranium bearing rock not of ore grade, clinker, and sand and gravel can be mitigated by stockpiling materials in those cases where mining and construction threaten loss by disturbance of the ground. To the extent these resources are part of the federal mineral estate, operators will be required to segregate, stockpile, or otherwise isolate the resource for possible future use.

Archeological Preservation

Legislative authorities and obligations which guide issuance of federal license to develop the Powder River coal resources are the statute commonly referred to as Antiquities Act of 1906 (34 Stat. 225, 16 U.S.C. 431-433); Wyoming statutes relating to archeological and paleontological sites (sections 36-11 to 56-13 and 18-330.7 W.S. 1957); Wyoming Environmental Quality Act of 1973 (Section 35-502.12(a)(v)); an act for salvage at reservoir sites (74 Stat. 220; 16 U.S.C. 469-469c); an act for historic preservation (80 Stat. 915, 16 U.S.C. 470-470m); National Environmental Policy Act of 1969 (83 Stat. 852, 42 U.S.C. 4321 et seq); and Executive Order 11593, May 13, 1971 (36 F.R.-8921).

Both federal and state antiquities acts regulate antiquities excavation and collections, and both protect historical values on public lands. They provide for fine and/or imprisonment for violators of their provisions. The Wyoming Environmental Quality Act protects areas of the state designated unique, irreplacable, historical, archeological, scenic or natural. The reservoir salvage act provides for recovery of historical and archeological data from areas to be inundated by certain water impoundment as a result of federal action. The Historic Preservation Act established a system of historic preservation in the nation and requires that certain federal undertakings be submitted for review by the National Advisory Council on Historic Preservation. NEPA states in Section 101(b)(4) that one objective of national environmental policy is to "preserve important historic, cultural and natural aspects of our national heritage and maintain, wherever possible, an environment which supports diversity and variety of individual choice." Finally, Executive Order 11593 affects federal agencies most intimately in that they are instructed to cooperate with the nonfederal agencies, groups, and individuals and to insure that federal plans and programs contribute to the preservation and enhancement of nonfederally owned historic and cultural

values. Agencies are directed to inventory, evaluate and nominate properties in their jurisdiction to the National Register of Historic Places.

Under the mandate of the Executive Order, federal agencies must insure that until inventories and evaluations are completed, the agencies will use caution to assure that federally owned properties which might qualify for nomination to the National Register of Historic Places are not inadvertently transferred, sold, demolished, or substantially altered and that federal plans and programs contribute to the preservation and enhancement of nonfederally owned sites.

The Antiquities Act of 1906 prohibits damage or excavation of plant and animal antiquities on federal lands without a permit (see 43 CFR Part 3). The Wyoming statutes require that permits be obtained before excavation of any archeological or paleontological deposits on either state or federal public lands (sec. 36-11 W.S. 1957).

Archeological and paleontological values on federal lands will be protected by surveys and salvage excavations. The Wyoming Antiquities Act similarly requires a permit for excavation of antiquities on public lands, permission to be granted by the State Board of Land Commissioners.

The Wyoming Environmental Quality Act requires approval of any application for a mining permit under the provisions of Section 35-502.24 (g)(iv) of this Act to assure that "...the proposed operation will not irreparably harm, destroy, or materially impair any area that has been designated by the Council to be of a unique or irreplaceable, historical, archaeological, scenic or natural value."

Surface surveys for evidence of archeological values in the alluvium are fundamental to establishing responsible stipulations for their protection. Therefore those stipulations in the mining plan and/or permit that require surveys will be followed to insure archeological and paleontological protection.

No mining plans, permits or rights-of-way will be approved until the company has coordinated its archeological surveys with the Wyoming State Historic Preservation Officer. Company survey reports will be submitted to the State Historic Preservation Officer with a copy to agencies approving plans and permits. The report will be certified by the Preservation Officer and forwarded to the approving agencies with a statement that surveys have been conducted by competent, professional archeologists and a recommendation for additional surveys to be required before plans and permits are approved. These additional surveys may be necessary if surface evidence indicates further evaluation is necessary. In addition, approvals will be conditioned to require notification to the Area Mining Supervisor of all archeological and paleontological sites discovered during mining prior to disturbance and notification to the appropriate officer of the surface administrating agency of sites discovered during right-of-way construction prior to disturbance. The Antiquities Act of 1906 and Wyoming statutes make it unlawful to excavate sites which are discovered without a permit.

Furthermore, it will be required that the alluvium to be displaced during the mining operation be surveyed and that all surveys be coordinated with the Wyoming State Historic Preservation Officer to insure competent, professional inventories, salvage, and preservation of archeological and paleontological data.

All present and future applicants could share in the cost of establishing a full-time resident basin paleo-archeologist under the supervision of the Wyoming State Historic Preservation Officer. The basin archeologist would aid in reducing lead time and development delays by performing advance surveys for support facilities, educating construction employees, sampling soils, responding to company discoveries, and conducting salvage work.

Historical Values

Authorities for protection and preservation of historic values are the same as those just described for archeologic values. Historic values are protected by the antiquities acts, and surveys conducted to ratify requirements of the reservoir salvage law have included historic research.

To meet responsibilities under these laws and the executive order, the approving federal agencies will insure that mining plans and permits include a program for historic inventory, evaluation and nomination of sites, districts, buildings, and objects, in cooperation and consultation with the State Historic Preservation Officer.

Recreation

Requests for water impoundments to supply expanded power generating, coal development and domestic uses occupying federal lands and threatening important cultural values and related recreational use, can be granted pending decisions by the State Engineer through the authority contained in the Reservoir Salvage Act of 1960 (74 Stat. 220) and the National Environmental Policy Act of 1969 (83 Stat. 852, 42 U.S.C. 4321 et seq).

If a planned reservoir covers federal surface or mineral and its water is designated for another federally approved project, it will first be assessed under the requirements of the National Environmental Policy Act and salvage requirements under the Reservoir Salvage Act. If cultural values are located the "criteria for effect" under Section 106 of the National Historic Preservation Act and Section 2(b) of E.O. 11593 will be initiated by any federal agency joined in the project.

Where scenic, historic, and recreation values are impacted, either on or adjacent to federal land, it will be required that new federal aid highway study locations and alignments complement these resources under the Federal Aid Highway Act of 1973 (Sec. 134(a) P.L. 92-87).

Land Use Planning, Zoning and Controls

A description of the current status of planning, land use controls-constraints and zoning is contained in Chapter IV. The basic situation is that a multiplicity of jurisdictions and agencies are involved in establishing policies, conducting planning, analyses and studies and implementing program actions in response to coal development. The State of Wyoming presently has at least three entities which are in some way involved with policies, planning analyses and studies, and program actions. They are the Land Use Study Commission, Department of Environmental Quality and the Governor's Energy Task Force. However, in the absence of a major overall and restructuring of existing statutory authorities and the land and resource tenure arrangements, it is possible to suggest several mitigative measures and techniques that could have a beneficial effect upon the planning base. Among these are the following:

> The exemption of minerals and minerals development from county planning and zoning should be removed by legislative action while providing for a state override role on planning and zoning for minerals development. The authority in any legislation should go beyond just planning but should include management and enforcement responsibilities. The legislation should foster more joint powers agreement, a greater degree of regional planning, the changing roles for state and local governments in land use controls and the changing awareness or philosophy of land as a resource rather than a commodity.
>
> Encourage a strict enforcement of the provisions and regulations imposed by the Wyoming Environmental Quality Act of 1973 with a

continual monitoring program on industry performance to identify nonperformance problem areas and areas needing further legislative attention.

Amendment to the existing statutes on planning which would change the authorization to effect planning and zoning from a county option basis to a required basis with procedural provisions included to effect compliance.

Institute review and comment cycles at the state and local levels on all types of planning actions and programs.

Encourage an integrated (federal, state and local) approach to all planning programs that relate to land use or resource allocation plans, policies or controls.

Advocate legislation that would increase the level of appropriations for federal agencies to be devoted to planning activities under their existing planning and resource development systems to upgrade the quality and substantive content of plans and intensify the time schedule for earlier completion of plans and implementation programs.

Same with respect to state and local agencies and governments.

Same, but to include additional increases for plan implementation and control functions such as monitoring, enforcement, compliance review, etc.

All future legislation and regulations should require public hearings or other disclosure of proposed federal, state and local plans and programs.

Encourage full public participation, to the maximum extent practicable, by the general public and special interest groups in the planning decision-making processes.

Railroad Construction

Impacts on the region's rail transporation network can be mitigated to a degree under the authority contained in Section 1 (18) of the Interstate Commerce Act (49 Stat. 543, 49 U.S.C. 1 (18)) which requires the prior approval from the Interstate Commerce Commission for the extension or new construction of a line of railroad or the abandonment of operation of a line of railroad. Exempted from this authority are spur, industrial team, switching or side tracks located wholly within one state. Section 1 (18) requires a certificate from the Commission that any construction, extension or abandonment is warranted by the present or future public convenience and necessity.

An intent of the statute is to promote sound economic conditions among individual carriers while recognizing the needs of the shipping public. For an application for new construction, consideration is given to the need for additional rail service in a particular area. If a new line would create essentially duplicative or unnecessary facilities or if the present or future demand for rail transportation is not supported by an area's overall growth and developmental patterns, an authorizing certificate may not be issued. This could arise where a new line, if authorized, would divert substantial portions of the traffic handled over an existing line thereby potentially creating an unprofitable operation which may affect the general adequacy of rail service as well as the financial health of the railroad company. In addition, even if demand patterns may warrant an expansion or additional line, the actual authorized location of such a line would be determined based on a balancing of the relevant economic, technical, and environmental factors. The prior authorization requirement applies to new rail right-of-ways as well as to additional lines in an existing rail right-of-way.

The statutory intent behind prior authorization for railroad abandonments is similar. Here the financial stability of a railroad company may be impaired where a line with declining freight revenues must nevertheless continue to be maintained or rehabilitated. Substantial expenditures may be required on a line with minimal traffic at the expense of maintenance over more highly trafficked lines. This factor, however, must be weighed against the present or potential need of the shipping public for continued rail service and the corresponding effect on the economic vitality of a particular area.

The net effect of the regulatory scheme under the Interstate Commerce Act is thus, to the extent practicable, to promote the availability of rail transportation when and where it is required. As an adjunct to the regulatory functions the Act further provides in Section 1 (19) that public notice of any application for a certificate must be given with a related right to be heard. In this manner the public will be fully informed prior to any major alterations, either additions or deletions, to an area's rail network.

Finally, since applications for construction or abandonment are considered federal actions, the certification process must comply with the provisions of the National Environmental Policy Act of 1969. Environmental values will thereby be incorporated into the pertinent decision making process.

CHAPTER VII

PROBABLE ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

Climate

Since emissions cannot be completely controlled an increase of atmospheric particulates is anticipated.

Vehicle and equipment emissions, airborne dust resulting from coal mining, emissions from power plants and gasification plants will result in a cumulative decline in air quality which may result in an adverse impact to climate which would be unavoidable. Therefore, effects of reduced precipitation on agriculture, mined land rehabilitation and water supplies would also be unavoidable.

Air Quality

Development of coal resources in the region together with related activities will have an unavoidable adverse effect on local and regional air quality. Increases in particulates, sulfur dioxide, nitrogen oxides, trace elements (including radionuclides), and hydrocarbons will occur even though emission controls are employed and air quality standards are enforced. These emissions will decrease the ambient air quality in parts of the Wyoming and Casper intrastate air quality control regions.

Deleterious stack emissions cannot be completely eliminated with existing technology so adverse impact to air quality is unavoidable. Table 1 gives total estimated stack emissions per year for 1980, 1985, and 1990.

Table 1

Estimated Stack Emissions
(tons/year)

Year	Particulates*	Sulfur Dioxide*	Nitrogen Oxides*	Hydrocarbons**
1980#	7,200	70,100	48,000	39,500
1985##	13,700	134,300	90,000	79,000
1990###	16,000	155,700	106,100	79,000

*Assumption: New power plant emissions will meet New Source Performance Standards (NSPS) and Wyoming Air Quality Emission Standards.
**Estimated emission from gasification plants only.
#Total power plant capacity 1,425 megawatts.
##Total power plant capacity 2,700 megawatts.
###Total power plant capacity 3,200 megawatts.

Emissions resulting from daily operation of 24 trains by 1980, 34 by 1985 and 46 by 1990 cannot be avoided. The total emissions as shown in Chapter V, Table 2, cannot be avoided, as there are no emission controls applicable to diesel locomotives. These emissions will add to the cumulative adverse impact on ambient air quality.

Vehicle and equipment emissions will increase during the period 1974 to 1990 even though controls are required. The number of vehicles in Campbell and Converse Counties is projected to increase 43 percent over 1970 levels. Additional miles will be driven as workers commute to the mines, power plants and gasification plants.

An indeterminable increase in airborne dust and similar particulate matter (coal dust, fly ash) resulting from coal development activities will be unavoidable even if all mitigating measures are applied.

Short-term adverse effects are not expected to be significantly harmful to either humans, animals, or vegetation, except possibly during periods of inversions. The probability of a two-day inversion occurrence is 15 times per year, and a five-day inversion is four times a year. (Observations by Marwitz indicate persistent winter inversions -- Hearings Statement 6-26-64.) During these periods, significant short-term adverse effects may occur.

Long-term unavoidable damage to plants, animals and humans from air pollutants may occur and be unavoidable. Even though air quality standards are met by each individual plant or source, the adverse effect of coal development in the study area will be a cumulative decline in air quality. Such a decline would be unavoidable and would begin in 1975, increase during the period of 1975 to 1990 and would continue as long as coal was mined and consumed in the study area.

Table 2 projects increases in air pollutants over the 1970 levels in the Casper and Wyoming intrastate air quality control regions.

Table 2

Total Emission Summary for Casper and Wyoming Intrastate Regions
(tons/year)

	1970	1980		1985		1990	
Type	Total*	Total	Increase**	Total	Increase**	Total	Increase**
Particulates	120,649	128,115	6%	134,733	12%	137,162	14%
Sulfur Dioxide	63,389	134,095	112%	198,564	213%	220,259	248%
Nitrogen Oxides	93,264	145,201	56%	188,943	103%	206,961	122%
Hydrocarbons	67,362	107,862	60%	147,805	119%	148,292	120%

*Combined total for Casper and Wyoming Intrastate Air Quality Control Region adapted from Wyoming Air Quality Standards and Regulations, 1973.

**Percent increase over base year (1970); includes stack and train locomotive emissions.

Topography

A reduction in altitude caused by mining thick coalbeds beneath thin overburden throughout 14,000 acres by 1990 is unavoidable. The decrease in elevation is directly related to the ratio of overburden to the thickness of the coalbed. Greatest decreases in altitude will occur in areas of thinnest overburden and thickest coalbeds. Lowering of altitude on a north-to-south basis will vary from 54 feet at the North Rawhide mine (Carter), 68 feet at Wyodak mine, 36 feet at Black Thunder mine (A.R.Co.), 38 feet at Jacobs Ranch mine (Kerr-McGee), and 28 feet at the proposed Rochelle mine (Peabody).

Destruction of natural features of the landscape is unavoidable. Even though the general topography of the area can be restored at a lower level, cliffs and abrupt breaks, presently a part of the topographic scene, cannot be restored. The exact shape and slope of the present topography is unrestorable.

Changes in topographic features caused by deep cuts along the proposed rail line cannot be avoided. These will affect topography over a small portion of the entire study area. The impact may be very significant on the exact site but overall magnitude will be minor.

Drainage pattern changes and possible creation of new patterns is unavoidable. Even though these changes may be minimized by utilization of sound planning of operations, a certain amount will still occur.

Soils

Disturbance of topsoil on approximately 29,000 acres (0.6 percent of the study area) by 1990 cannot be avoided. Loss of productivity from 9,500 acres of topsoil by 1990 is unavoidable. This acreage will be occupied by roads, railroads, mine buildings, gasification plants, and power plants. The disturbance of topsoil will lower to some degree the natural soil productivity of the area by compaction, mixing natural soils, and causing accelerated soil erosion.

On the area to be strip mined, 14,000 acres by 1990, complete destruction of all soil horizons, parent material, and soil characteristics which have developed over long periods of geologic time cannot be avoided. The present soil biota and soil forming processes will be terminated. Once mining is completed and the area reclaimed, soil development will start again. As an end result of mining, new soils will be formed with characteristics totally unlike the ones existing prior to mining and, during their early geologic life, likely less suitable as substitutes for vegetation growth.

Reduction of soil productivity, permeability and infiltration rates is unavoidable. Increase in erosion and sedimentation rates will occur, but amount of soil loss through time cannot be determined.

Mineral Resources

The mining and removal of coal cannot be avoided under present plans and proposals. Thus, coal mining activity will have an unavoidable adverse effect on the coalbeds. Coal reserves, a nonrenewable mineral commodity, will be depleted. Based on company plans and projections, an estimated 1.5 billion tons of coal will have been mined by 1990 which comprises 12 percent of the estimated economically recoverable strippable coal reserves thus far identified in Campbell and Converse Counties and about 11 percent of the reserves identified in the Northern Great Plains of Wyoming. Loss of minor amounts of coal in mining operations and transportation is unavoidable.

Coal beneath and adjacent to the proposed railroad right-of-way undergoes impact only in that the present value of the coal and/or coal land is decreased because mining is delayed until futher in the future. Although this impact is unavoidable, it is adverse only in the economic sense.

Small amounts of uranium-bearing material might be unavoidably lost through dilution of grade and covering of weakly mineralized rocks in the course of coal mining and construction. The loss would be minor.

Water Resources

The increased use and consumption of water (52,220 acre-feet per year) in the study area by 1990 cannot be avoided. The exact amount which will be consumed and unavailable for other uses is indeterminable and unavoidable. The removal from the study area hydrologic cycle of an estimated 15,000 acre-feet per year by 1990 in the coal slurry pipeline cannot be avoided.

The adverse impact resulting from the interruption of aquifers during mining cannot be avoided. Lowering of water levels of wells, and drying up of springs, seeps, and reduction in streamflow will occur in an area around the mine when aquifers are disrupted. The location and extent of this cone of depression around the mined area will vary depending on various aquifer properties.

If large quantities of ground water are withdrawn from thick sand and shale aquifers, some subsidence may result. Increasing use of ground water as proposed may affect water well levels and discharge of ground water to streamflow. Reduction in flows throughout the study area would be adverse.

Development of lakes, ponds, and pits of water at the completion of mining cannot be avoided where thick coalbeds are mined which have thin overburden levels. This will be adverse to the extent that it depletes streamflows and adds to evaporation loss of water which then is not available for other uses (agriculture, stream fishing habitat).

Changes in water use from agricultural and irrigation uses will occur. These changes, although involving water uses, will actually have adverse, unavoidable impact on farming, grazing, and recreation land uses as well as on fish and wildlife populations.

Reduction in water quality resulting from increased erosion, sedimentation, overtaxed sewage facilities, release of toxic waste to streams, and return of production water to stream channels will take place. The overall reduction in water quality which will take place is unknown.

Vegetation

Existing vegetation will be destroyed on the mined areas, plant sites, housing sites for increased population, transmission line and pipeline rights-of-way, roads and railroad rights-of-way. There will be an unavoidable permanent loss of vegetation on 9,500 acres by 1990 due to construction of permanent facilites. Vegetation will be temporarily destroyed on 14,000 strip mined acres by 1990.

Areas disturbed by rights-of-way will be reclaimed shortly after disturbance. With the semiarid climate prevalent for the study area, successful revegetation on the severely disturbed mined areas is unknown at this time.

All plant succession is unavoidably destroyed at the time of disturbance. Fifty years or more of plant succession will be required for these areas to return to their present state as the existing soil structure and microclimate have been changed and altered.

Adverse impact of stack emissions, especially sulfur dioxide, on vegetation is unknown. The impact, particularly on ponderosa pine, will be unavoidable. Increased population will intensify recreation use which will destroy or decrease the vegetative cover depending on the amount of use an area receives.

Archeological and Paleontological Values

Subsurface material and sites will be damaged or destroyed under the most responsible mining program, with much more lost from surface activities of population expansion.

Some losses, removal of 9,500 acres by 1990, to regional expansion will be expected from lack of surface evidence, time, money, and trained personnel to conduct regional surveys.

Historical Values

Impact on the historical sites: Cantonment Reno, Fort Reno, Hoe Ranch, Portuguese Houses, Powder River Crossing and Red Cloud Agency, from increased population with attendant increase in vandalism and pot hunters cannot be totally avoided. Some damage to these sites will undoubtedly occur as a result of development within the basin.

Visual impacts resulting from construction of rail line, transmission lines, mine facilities, especially silos, and industrial plants are unavoidable. All of the identified historical sites could be impacted visually at some time during the time span required to exhaust the currently economically strippable coal resource.

Some physical impact, despite all precautions, during road building activities, may occur on the following historical sites: Antelope Springs, Minor Bozeman Trail Sites, Crazy Woman Crossing, Seventeen Mile Stage Station and Suggs. Increased access will increase the use pressure on all historical sites and could result in unavoidable damage.

Aesthetics

The change in scenic characteristics throughout the study area cannot be avoided. The major changes will take place in the area of strippable coal reserves. The landscape will be crossed by transmission lines, new road and railroad cut and fill slopes. Vegetative patterns will be altered on rights-of-way and mined areas. New vertical intrusions will be added to the landscape (plant buildings, loading silos).

The change of the study area from a quiet rural setting, with wide open spaces, basically uninhabited to a basin busy with industry and human activity is unavoidable. The quiet solitude and natural peacefulness of the area will be changed.

Wildlife and Fish

Loss of habitat and reduction in populations will occur as a result of coal mining and utilization operations and will be unavoidable. Increased hazards, permanent habitat losses and deteriorated habitat will result in a loss of approximately five percent (850 deer) from the nearly 17,000 deer winter herd in the study area. Approximately 14,500 acres of deer range, including 1,400 acres of key range will be lost.

Antelope will be similarly adversely impacted. Approximately 10,000 acres of year long habitat and an additional 19,000 acres of winter range will be lost, resulting in a nine percent reduction (2,700) of the base population of the study area of 30,300.

In all probability, the 300 head of elk currently using the area will be forced from the area and possibly lost if unable to find other suitable habitat.

Destruction of aquatic habitat and species will occur when streams are altered to allow mining. Amount of loss is indeterminable. Water quality will be reduced, thereby affecting additional aquatic life.

An estimated three percent to four percent (940 to 1,250 birds) of the base sage grouse population in the study area will be lost. This loss will be associated with the loss of 29,750 acres of big sagebrush vegetative type by 1990.

Habitat removal and severe disturbance will result in a direct and permanent loss of sharp tail grouse. Total population numbers are unknown so actual loss cannot be quantified.

Change and elimination of ponds, streams and reservoirs will adversely impact waterfowl. The temporary loss of this water base during mining operations

is unavoidable. Based only upon known aquatic habitat areas where losses appear likely, an estimated loss of 400 to 800 ducks may occur.

Cottontail and jackrabbit populations will be reduced. By 1990, cottontail and jackrabbit populations of about 148 and 101 per square mile, respectively, will be lost on 28 square miles (estimated 7,000 rabbits).

Substantial losses of small mammals will occur. Populations of some rodents such as the deer mouse, least chipmunk, and sagebrush vole will be destroyed or severely reduced on roughly 29,000 acres by 1990.

Recreation

The increased population in the basin will intensify recreation demand. The increased demand could cause deterioration and overuse throughout the area and on existing facilities (Little Thunder Reservoir and Little Powder River Wildlife Area in the National Grasslands, Devils Tower, Keyhole, Guernsey and Glendo State Parks). The generally unavoidable adverse effect is the lowering of recreation quality within the study and adjacent areas.

Agriculture

The permanent cumulative loss of 4,800 acres by 1980, 7,900 acres by 1985, and 9,500 acres by 1990 of agricultural land is unavoidable. The return of agricultural land to production after reclamation depends on rehabilitation success. To determine unavoidable losses, a five percent rehabilitation failure and 10 percent conversion to other uses was assumed. The loss of agricultural production during periods of mining, construction, and rehabilitation cannot be avoided.

Livestock forage

Cumulative forage lost will be 1,515 animal unit months (AUMs) by 1980, 3,435 AUMs by 1985, and 5,067 AUMs by 1990. By 1990, this will amount to four-tenths of one percent of the total forage produced in the study area.

Increased vandalism of livestock watering facilities and fences cannot be avoided. Separation and alteration of ranching operations will occur. Drying up of livestock water sources will occur and ranchers will be inconvenienced by changes in access patterns and use patterns. Increased mortality and molestation of cattle and sheep will take place.

Farming

Cumulative amount of cropland which will be unavoidably lost is 650 acres by 1980, 1,019 acres by 1985, and 1,245 acres by 1990.

Irrigated cropland will be lost due to water right conversion. Total acreage lost due to lack of water is 31,473 acres by 1990.

The unavoidable cropland loss by 1990 would be approximately seven-tenths of one percent of the total available agricultural land within the region.

Transportation Networks

Increased traffic on all existing facilities within the study area cannot be avoided. The increase will begin in the 1975 to 1980 time period, peaking during the 1980 to 1985 interval and probably remaining fairly constant or with very slight increases beyond 1990. This will mean that road maintenance costs and frequency will increase and these costs cannot be avoided.

Temporary inconvenience and poor travel conditions caused during construction of such facilities as the rail line, coal slurry and gasification pipelines are unavoidable. These impacts will be minor and occur only over a short time span. It is impossible to predict the possible increase in train/car accidents. With the number of trains required per day (46 by 1990), the increased probability of these accidents occurring cannot be avoided.

The impact of additional trains on the existing mainline track cannot be avoided. Deterioration of the track and the necessity of having to upgrade the track and impacts associated with this upgrading cannot be avoided. The impacts associated with upgrading will be similar to the impacts discussed in Part II of this statement on construction of the new rail line between Douglas and Gillette.

Socio-Economic Conditions

Population

While the addition of population may not necessarily be adverse, the impact of population growth may generate negative effects. The residual impacts of population can best be discussed by component.

The expected introduction of intensive coal and other industrial development in the Eastern Powder River Coal Basin will induce a regional population increase from 107,364 in 1970 to approximately 167,000 in 1990. The Counties of Campbell and Converse will experience the greatest percentage increases in population. Additionally, over 78 percent of anticipated regional population growth in 1990 will occur in Campbell and Converse Counties. Population in Campbell County will rise from a 1970 level of 12,957 to a 1990 level of 50,400; population in Converse County will grow from a 1970 total of 5,938 to a 1990 total of 15,200.

Employment

A local unavoidable effect will be the attraction of labor from the agriculture, petroleum, and other residentiaries sector into the coal related sectors. This competition for labor will create short-term labor shortages in petroleum and other residentiaries to be filled as coal employment levels off. As a rule, the other residentiaries sector will lag behind coal because newcomers to the area will be expected to arrive for the purpose of coal employment and construction, and not other employment. The labor loss from agriculture will likely be long-term and it may never regain its former employment stature.

The unavoidable effect that large quantities of employment opportunities will be created is largely a consequence of the decision to allow development; such new employment can only be satisfied by importing adequate quantities

of labor into the region. A further consequence in Campbell and Converse Counties will be to hasten the conversion from an agrarian to an industrial economy.

Housing

Industrial development will induce new population that will demand housing. Regional population in 1980 will demand about 46,400 housing units, nearly 9,000 housing units more than the 1970 existing regional stock. As Campbell and Converse Counties will be the locations that receive the greatest population growth, housing stock in Campbell and Converse Counties by 1980 will need to expand by factors of 2.4 and 2.0, respectively, to meet the anticipated demand. Regional housing demand in 1990 will increase to 53,500 units which is 16,000 more than the 1970 stock. Housing demand will grow in Campbell County from 9,500 units in 1980 to 14,800 units in 1990, while housing demand will expand in Converse County from 4,400 units in 1980 to 5,100 units in 1990. The induced population will demand housing which does not now exist.

As housing probably will not be immediately available, the adverse impact of the incoming population having to accept inferior quality housing cannot be avoided.

Education

The impacts on public education as discussed in the Impacts Section are unavoidable. If coal resources are developed, the region will realize a substantial growth in population, which includes school age children. Public school districts, especially in Campbell and Converse Counties, would realize unavoidable increases in student enrollments, which in turn would impact existing school enrollment capacities and full-time teaching staffs. By 1990, Campbell County is projected to have a 8,360 pupil enrollment over

present capacity and need 426 more full-time teachers. Converse County would experience a similar situation although of a lesser magnitude. Converse County by 1990 would have a pupil enrollment of 1,280 over present capacity and need for 91 additional full-time teachers.

If increasing enrollments are not accommodated adequately, the following impacts could result:

1. Overcrowded classrooms in existing schools;
2. Student-teacher ratio imbalance;
3. Use of temporary structures (mobile trailers, modular units) for classrooms because of overcrowded and inadequate facilities;
4. Operating certain schools on a double session basis;
5. Inter-county bussing of students;
6. Reduction in quality of education.

Health and social services

Campbell and Converse Counties will experience an unavoidable increase in demand on their health and social services. There will not be enough physicians, dentists, professional nurses and other social workers to meet the demand. Quality of health care would be adversely reduced. Even though there may be sufficient facilities for the sick to be treated in, people would experience longer waiting periods for treatment. With the rapid population expansion and lack of sanitarians, public health and safety hazards may increase, affecting the entire regional population.

Law enforcement

The impacts on law enforcement as discussed in the Impact Section are unavoidable. If coal is developed, the regional population will expand, creating

a need for increases in police manpower and facilities. The demand for increases in full-time sheriff personnel and full-time municipal policemen is unavoidable.

By 1990, Campbell County would experience a demand for a total of 50 sheriff personnel, a deficit of 42 based on presently available personnel. Converse County by 1990 would have a demand for a total of 15 sheriff personnel, 9 over the number presently on the force. Municipal police departments would experience the same type of increased demand. The Gillette department would have a deficit of 31 people and 11 patrol vehicles by 1990. Douglas would have a deficit of 7 people and 2 patrol vehicles by 1990.

With or without increases in law enforcement personnel, crime incidence will most likely rise. The magnitude of this rise is dependent upon too many variables, which make crime level predictions very difficult and nearly impossible. If adequate levels of enforcement personnel are not provided, intolerable conditions could be encountered in some areas.

Fire protection

Unless expansion is undertaken by communities, deficiencies in water pumping capacity will have the unavoidable effect of diminishing a community's ability to adequately meet hazardous fire conditions. Greater structural fire damage will result, and ability to respond to simultaneous fires will be diminished.

Water and sewer facilities

Water

Current treatment facilities will be unable to meet the projected demand. By 1990, Gillette will have a treatment deficiency of 12.2 million

gallons per day and Douglas would have deficit of 2.2 million gallons per day. The present distribution system would be inadequate for both of these communities by 1980. Adverse unavoidable impacts could occur (use of low quality water, increased sickness, poor health) from not providing adequate water treatment and distribution systems.

Sewer

Current collection and treatment facilities for Douglas and Gillette will be overutilized by 1980. In 1990, Gillette will have a collection capability deficiency of 2.9 million gallons per day and a treatment deficiency of 3.3 million gallons per day. Douglas, by 1990, will experience a deficiency of 700,000 gallons per day in its collection and treatment facilities.

Overuse of the sewage facilities could result in the unavoidable adverse impact of more sewage being dumped into stream channels (Donkey Creek, North Platte River).

Utilities

Regardless of the degree of planning, certain impacts may be unavoidable. Douglas is faced with possible telephone service delays if it grows to the north and it may likely incur delays in all types of utility service if a coal gasification plant with its large employment locates nearby. The Cities of Gillette and Newcastle may be faced with a natural gas shortage if a large number of new base hookups are required. The actual extent to which the supposed natural gas shortage exists was not known to the local distributor inasmuch as he in turn purchases his gas from a regional supplier. Distributors to the other communities did not express a similar problem. Present construction material shortages may worsen if utility companies must acquire increasingly larger amounts of materials to satisfy consumer service requests.

CHAPTER VIII

ALTERNATIVES TO THE PROPOSED ACTION

No New Development

The no new development or no action alternative would be to not allow any additional development of federal coal in the Eastern Powder River Coal Basin. Mining at the Belle Ayr south, Wyodak and Dave Johnston mines would be allowed to continue to completion on presently approved leases and mining plans. Selection of this alternative probably would not totally prevent development of new mines in the study area; private coal would undoubtedly be developed. The balance of the energy which was to be supplied by coal from the Eastern Powder River Coal Basin would have to be supplied from other coal areas or from alternate energy sources. Impacts associated with alternate energy sources are analyzed under the alternate energy source alternative.

Impacts

Coal-based industrial development (gasification and power plants) would not be feasible under this alternative. Impacts associated with gasification and power plant construction and operation would not occur (see Chapter V, this part). Development of the railroad may remain feasible under this alternative based upon the economics of utilizing the line for overhead or bridge traffic generated elsewhere. Vegetation and soil disturbance would not be as much as under the proposal. Ambient air quality would not be lowered as a result of stack emissions.

Impacts on the physical resources, wildlife, vegetation, and soils, would not occur on a major portion of the area under this alternative. Social-economic impacts would be lessened throughout the area. Community

facilities (schools, sewage and water systems, enforcement, social services) would not be impacted to the magnitude analyzed in Chapter V of this part.

Development of private coal could create a number of small strip mines with resulting environmental impact scattered throughout the entire area. Reclamation requirements on private coal may not be as stringent as federal requirements; and after mining, impacts on air quality (dust), water quality (increased erosion and sedimentation), and wildlife could be worse than the impacts associated with the proposal. Impacts on transportation networks may be worse than the proposal since truck transportation would probably be utilized to transport the coal to the main line railroad at Douglas or Wyodak. This would require construction of new roads or upgrading of existing roads. Impact of this type of transportation is analyzed under the alternate modes of transportation section.

Impacts associated with the three existing mines would continue. The impact of continuation of the Wyodak mine is analyzed in Chapter III, Part VI of this statement. Impact at the other two existing mines would be similar.

If energy demands are to be supplied by coal, suspending development of federal coal in the study area will shift impacts to other coal regions. Utilizing coal from another area such as Illinois, Kentucky, or Pennsylvania would create some impacts in those areas similar to those which occur in the study area if coal development is allowed. New mines would need to be opened or production expanded at old mines. Since most of the coal is mined underground, recovery would be less than the 90 to 95 percent

projected for the study area. Additional transportation would be required and since these areas are more heavily populated, construction of new or expanded transportation facilities could have an impact of greater magnitude than within the study area. Much of the eastern coal is of higher sulfur content; air pollution could become worse. Even though underground mining methods were utilized, there would still be the potential surface disturbance from subsidence. Any surface disturbance in these areas has the potential of destroying, or impairing the use of, more productive or potentially productive farmland.

Implementation

Implementation of this alternative would require Congressional action.

Restrict Development

Delay pending new technology

Although reclamation methods are being improved, techniques of handling soil, methods of planting, preparing the area and selection of plant species need to be developed and tested for this area. Native seed sources are necessary to supply seed in sufficient quantities to be used in revegetation.

Research into and testing of new emission control devices are proceeding at a rapid pace. Efficiency of utilization could also be improved within the near future. Methods of conversion of coal energy into clean energy (gasification) are also being developed and perfected.

Impacts

If development of federal coal is delayed, it is probable private coal in the study area will be developed. Impacts of coal development are discussed under the "no new development" alternative.

Even with development of private coal, it is doubtful if the companies can meet their contracts without federal coal. Therefore, the utility plants in the Midwest and South that were to receive the lower sulfur Eastern Powder River Basin coal would have to obtain coal elsewhere. Continued utilization of high sulfur coal at these plants will increase the impact on air quality at the point of utilization. A continued decline in ambient air quality in these areas could seriously impact vegetation and health

conditions, especially during inversion periods. Another possible result of unavailability of low sulfur coal and the requirement to meet air quality standards is that these plants would have to reduce generating capacity. This could result in blackouts, brownouts, reduction in economic development, and inability to supply consumer demands.

If development were delayed until new pollution controls, particularly for sulfur dioxide, were developed or perfected, the impact on air quality at the point of utilization would be decreased. At that time eastern utility companies could utilize eastern coal which is economically cheaper for them. This possibly would prolong development of Eastern Powder River Basin coal. Improvement of pollution technology would also reduce the impact on air quality from the development of power generating plants within the study area.

Whenever the coal is developed in the study area, impacts as described in Chapter V, Part I of this statement will still occur. However, the unavoidable adverse impacts would be reduced if reclamation and revegetation techniques suitable for the climatic condition of the study area are developed and perfected.

If revegetation methods were perfected, increased vegetation success and correspondingly lessened adverse impact on livestock forage and wildlife habitat may be expected. With development of adequate supplies of native plant seed sources and techniques for insuring survival, long-term impacts on wildlife habitat may be reduced from 20 to 50 years to 10 to 15 years or possibly even less. The projected productivity loss of 50 percent under current techniques possibly could be lowered to 15 to 25 percent loss. A decrease in the time required to revegetate, and an increase in the amount of cover returned, would reduce the amount of erosion and sedimentation

which takes place after mining. This would reduce the adverse impact on water quality which occurs after mining is completed.

An increase in utilization efficiency could possibly reduce the amount of coal mined per year. Mining less coal per year would spread the impacts over a longer time period, allowing for recovery prior to additional disturbance.

<u>In phase and staged with socio-economic development</u>

In lieu of the proposed action program, an alternative program could be undertaken that represents a marked departure in policy framework from the existing management modes historically adhered to by the Bureau of Land Management and Forest Service. This alternative would be to develop a natural resources management, development, and utilization program for the Powder River Basin region that would be coordinated with the rate of social and economic development that could be sustained by the communities within the region. With respect to the federal sector, this alternative could be implemented by utilizing the existing Bureau and Forest Service planning systems to develop and maintain land use plans while considering all of the various resource uses for federal lands.

The local government sector would have the problem of assurance or guarantees that coal development would in fact occur and that revenues required for public facilities would be available timely. Bond or other borrowing can not be based on development speculation.

Implementation of this proposal would be purposefully directed toward coordinating community development capabilities with the rate of coal production. New or expanded coal developments would be allowed and accommodated only to the extent they were mutually compatible with community

ability to meet social and economic needs and demands placed upon it by the additional development and employment. The proposal is to methodically phase in, over a period of years, the quantity of new coal development that will be allowed in order to enable the community to plan for and develop needed housing, educational and social services in advance of need rather than after these facilities have already become inundated and overcrowded. The total requirement for needed facilities might not be lessened appreciably, but the increase in demand for them would occur over a longer period of time; thereby, allowing communities to respond more effectively. Certain employment demands (particularly construction) could be reduced at any one time to allow more even utilization of those services over a longer time period.

This alternative itself would not lessen the intensity or magnitude of impacts on the physical resources sectors (agriculture, wildlife, water, etc.), but it might allow for future technological improvements (in vegetative restoration, pollution control, etc.) to be developed. Future implementation of technological advances could serve to lessen impacts on physical resources.

With respect to the existing contractual interest in coal, the practicability of this alternative is limited by the Federal Government's inability to implement staging or development without special Congressional authority. The Secretary of the Interior does have authority to suspend operations and production of leases in the interest of conservation, but such suspension must be limited to reasonable periods. Development of coal leases in the study area cannot be selectively delayed for extended periods unless authorities and funding are provided that allow the Federal Government to buy back the leasehold interests. Development controls would not apply to privately owned coal unless implemented by state government.

Control number of producers

The alternative of controlling resource depletion through controlling numbers of producers would require special legislation. In the American free-enterprise system, industry strives to meet demand. The demand for coal resources is real and will be met (if possible) by production of one supplier or by several hundred suppliers. If production is limited to one company, a monopoly is created. Governmental limitation of production to four, six or any other particular number of companies would create legal entanglements which would be detrimental to meeting demand.

Impacts

The impacts associated with having one or a few producers supply all the coal produced in the basin would be the same as discussed in Chapter V although all impacts would be concentrated in areas controlled by the few operators. Coal mining in producing areas would have to be accelerated which would allow reclamation work to be completed in a shorter time. This would produce a high concentration of workers and increase associated socio-economic and safety effects. As a result of completion of mining in a shorter time period, the economic effects would be more pronounced.

Control location of depletion by designating area for production

Other areas in Wyoming or the nation could be developed for coal rather than the Eastern Powder River Basin. Administrative designation of areas for coal development would require enactment of special legislation. The state might look favorably upon special legislation designed to enhance coal mining in other areas of Wyoming so that reserves in these areas

could be fully mined in an orderly manner before mining was permitted in the Powder River Basin.

Impacts

The possibility of enactment of this type of mineral and land use legislation is speculative. Such legislation would impact customary leasing procedures. Rights granted under federal coal leases would be denied and pending preference right leases might not be granted. Existing permits would be cancelled and competitive lease sales for coal would be deferred. Power plants presently operating would be allowed to continue operation, but a moratorium would be declared on plans for expansion of capacity. Mining and attendant activity would be held at approximately the present level. The Eastern Powder River Basin would not be industrialized to the levels described in this impact statement.

The impacts of this alternative in the Eastern Powder River Basin would be similar to those described under "No New Development" in this chapter. Private coal lands would still be amenable to mining where suitable private holdings exist.

Excavation for coal in another Wyoming coal basin would effectively transfer the impacts of mining and industrialization to that basin. Mining impacts on land and associated resources could be greater or less, depending on coalbed thickness at the alternate locality or localities. Thin coalbeds mined by surface or underground methods would likely require larger machinery to strip to maximum depth and greater numbers of employees, thus increasing impact in the industrial and socio-economic frames. Impact on water might

be less, given an adequate supply of water of sufficient quality such as a major stream of partially unappropriated water.

Areas of particularly high or unique resource values that are currently not under permit or lease that would be subject to serious environmental degradation by mining could be permanently set aside thus mitigating potential impact.

If companies with long-term contracts (30 to 40 years) were compelled to rely on private coal to meet commitments, demand could drive prices up. Under such circumstances islands of federal coal would be created that could result in coal resource waste because of highwall slope requirements at ownership boundaries.

Complete Exportation

This alternative considers the exportation of the coal out of the state for processing. The following assumptions were utilized for analysis of this alternative: (1) the 330-MW power plant at Wyodak will still be constructed since the state has already approved construction; (2) coal production levels and number of mines as analyzed for the proposed development will remain the same; (3) additional acreage will not be required by the railroad (according to a railroad spokesman); (4) the amount of powerlines and roads will remain the same; (5) the slurry pipeline will still be built; and (6) no additional power plants or gasification plants will be constructed.

Impacts

The impacts will be analyzed as of 1990 and compared with the projected impacts of the proposed development as detailed in Chapter V, Part I, of this statement.

Acreage disturbed by mining and reclaimed would remain the same as for the proposed action. However, under this alternative, the total disturbed area would be an estimated 24,300 acres, a 16 percent (4,700 acres) reduction from the proposed project. The area estimated to be permanently removed from production would be 4,800 acres, a 49 percent (4,700 acres) reduction from what would be removed under the proposed development. These reductions would reduce the impact on air quality, recreation, wildlife and agriculture.

Under this alternative the 1990 emissions and amount of decrease from the emissions under the proposed development are shown in Table 1.

Table 1

1990 Exportation Alternative Emissions*

Type	Amount	Decrease
Particulates	5,775	65%
Sulfur Dioxide	47,840	70%
Nitrogen Oxides	46,594	59%

*Includes train emissions.

The reduction in ambient air quality under this alternative would be substantially less than under the proposed development. However, the amount of train emissions will increase over what will occur under the proposal.

The number of trains required to transport the coal would increase. Under this alternative an estimated 21,818 trains per year would be required, resulting in an average of 60 trains per day. This is a yearly increase of 29 percent and a daily increase of 30 percent over the number occurring under the proposed development.

Without development of additional power plants and gasification plants, water requirements would not be as great. Under this alternative the estimated 1990 yearly water requirement would be 62,850 acre-feet or 31 percent less than the projected water demand for the proposed development. This reduces the probability of having to import water, as well as reducing the impact on agriculture which would occur under the proposed full development action.

Recreational impacts under this alternative would be less for several reasons: population increase would be less, reducing the number of people requiring recreation facilities; acreage disturbed and removed would be less; and fewer intrusions impacting the aesthetics of the region would be constructed.

Adoption of this alternative would result in a lessening of total adverse impacts on wildlife in most cases. The most recognizable change occurs in the amount of total habitat saved through "nonconstruction," an estimated 4,700 acres. It has been estimated that with exportation, Campbell County (most severely impacted under the proposed development) population projections by 1990 would be reduced by 13,900 people. The reduction of population estimates by nearly 14,000 people by 1990 would significantly reduce the amount of impaired wildlife habitat which would result from such factors as increased hunter and other recreational demands and miscellaneous habitat disturbances. Even though the general cumulative impacts involving loss of habitat and reduction in population as the result of coal development and associated activities remain the same as described for the proposed projects, the intensity of impacts on wildlife would be reduced under this alternative.

Impact on agriculture would be somewhat less under this alternative as compared to the impact as analyzed for full-scale development. Construction and development of facilities and mining would result in land use changes on approximately 24,300 acres. Of this amount, 4,800 acres or 19.8 percent would be permanently removed from production by construction of the railroad, Wyodak power plant, slurry plant, and population increase. Table 2 provides a comparison of the impact of this alternative with proposed full-scale development.

Approximately .56 percent of agricultural land would be disturbed and lost to production--not a significant change from the projections considering use of coal within the basin. The projected loss of annual livestock forage (16 percent - 822 AUMs less) and crop production would also change very little due to the assumption that land affected by coal mining and reclamation would remain virtually the same.

Year	Total Land Area Removed From Agricultural Production (Acres)	Land Removed From Livestock Forage Production (Acres)	Annual Livestock Forage Lost* (AUMs) 15"-17" Precipitation Zone 4.3 Acres/AUM	10"-14" Precipitation Zone 6.5 Acres/AUM	Total AUMs	Land Removed From Crop Production (Acres) Dryland	Irrigated**	Annual Hay Production Lost (Tons) Irrigated 1.62 Tons/Acre	Dryland .78 Tons/Acre	Total Tons	Annual Dryland Wheat Lost (Bushels) 18.6 Bushels/Acre	Other Cropland Lost (Acres) Dryland	Irrigated
1990#	(29,000)	(27,934)	(2,274)	(2,793)	(5,067)	(616)	450	549	(254)	(803)	(4,129)	(68)	111
1990##	24,300	23,401	1,905	2,340	4,245	459	450	549	190	739	3,088	50	111

*Assumes that 35 percent of the land disturbance will occur in the 15"-17" P.Z. and 65 percent in the 10"-14" P.Z.

**Acreage assumes most irrigation land will be lost in the Douglas vicinity mainly due to urbanization with a projected 50 acres loss per 1,000 increase in population.

#Losses associated with proposed full-scale development within the study area.

##Losses associated with this exportation alternative.

Projected Agricultural Loss

Table 2

Secondary impacts to agriculture would remain essentially unchanged whether coal is shipped from the basin or converted to other energy forms.

Impacts to irrigated cropland would still be anticipated due to the projected expansion of Douglas. Irrigated cropland affected by industrial water conversion would be significantly reduced (66 percent - 20,863 acres) as projected in Table 3.

Table 3

Projected Cumulative Loss of Irrigated Cropland
Due to Water Right Conversion

	Projected Annual Industrial and Municipal (Acre-feet)	Irrigated* Cropland Lost (Acres)
1990**	34,620	31,473
1990***	11,667	10,606

*Assuming 1.1 acre-feet of water is used per acre of cropland.
**Full-scale development as proposed for the study area.
***Exportation alternative.

Implementation of this alternative would cause a substantial decrease in both basic and secondary employment. Effects of the decrease in employment would be centered in Campbell County because the eliminated facilities were assumed to be located in Campbell County. From the decrease in employment, a drop in population increase would also occur. The 1970 population of Campbell County of 12,957 was estimated to reach 50,400 by 1990 under the proposed action assuming conversion facilities were constructed. By eliminating those facilities from consideration, the estimated population increase for 1990 is now 36,600 which is 27.4 percent less than predicted under the proposed plan of development.

Since the estimates of social services and facilities that would be required by the expanding population (Chapter V, Part I) are based on the size of the population increase, it can be assumed that the demand for all the social services and facilities in Campbell County will be about 27 percent less than calculated for the proposed action. Thus, the deficits noted in Chapter V, Part I, of this statement for housing, educational facilities, health and social services, law enforcement and water and sewer facilities would be 27 percent less. The 1990 requirements for social services and facilities under this alternative would be only slightly higher than the previous projections for 1980 needs, since the former 1980 population projections are only 4,400 less than the new 1990 projection.

Alternate Extraction Methods

Underground mining

Underground coal mining can be categorized into two basic methods, room and pillar mining, and longwall mining.

Room and pillar mining

This method involves driving comparatively wide openings (rooms) from haulways (entries or headings). Pillars between rooms and other openings support the roof. Recovery under normal mining conditions usually averages between 55 and 60 percent of the coal in place where the entire height of the bed can be mined.

Because of frequent presence of gas and explosive dust, thorough ventilation of the mine is required. Ventilation is provided through openings driven in sets. Fresh air enters by one or more openings, the intake, and leaves the mine by other openings, the return.

Main entries are driven from the shaft, or from the surface; from these, cross entries are driven and rooms are then developed off the cross entries.

Size of entries will be determined by two factors: (1) entries must be large enough to insure adequate ventilation and (2) entries must be narrow enough to support the roof and prevent floor heaving. Entries are usually 10 to 20 feet wide. Pillars are usually spaced on 60- to 100-foot centers and must be large enough to support the roof, haulage ways and airways and, if necessary, specific areas on the surface. Distance between sets of cross entries depends on length of rooms with the room lengths depending on characteristics of roof, floor and coal and the system of haulage and ventilation. Rooms are commonly 300 to 500 feet long, and where only turned in one direction

provide an entry spacing of 350 to 400 feet. Where rooms are turned in both directions off cross entries, the entry spacing is between 700 and 800 feet. Direction and location of all entries and rooms depends largely on size and shape of the property, surface conditions, dip of beds, amount of water, etc.

Robbing of pillars consists of removing the coal left for roof support after all development work is completed. Robbing begins at the end of the mined area and retreats back toward the main entries. Room and entry pillars are extracted in one operation. The method and time when pillar robbing should be done is determined by roof and floor characteristics, texture of coal, thickness and dip of coal, presence of gas and other local conditions. Where possible, all pillars are removed except those left to support specific areas on the surface.

Underground mining involves use of several types of hauling and mining equipment. Hauling equipment may consist of belt conveyors, rail, battery operated haulers or a combination of these systems. Mining may consist of conventional systems, where the coal is drilled and blasted, or continuous systems, where the coal is removed by continuous mining machines. In both cases, the coal is loaded into battery or electrically operated shuttle cars which in turn transfer the coal into mine cars or onto belt conveyors for transport from the mine.

Longwall mining

The development of longwall mining is basically the same as that involved in room and pillar mining with the exception of development of rooms. The rooms or panels are developed by first driving two sets of entries (two or three entries in each set) perpendicular to the cross entries. The

two sets of entries are usually 200 to 500 feet apart. Once the two sets are driven the desired distance, they are connected by two or three entries which form the operating face. A coal shear or plow is set up along the length of the face. The plow operates by chain drive and is pulled back and forth across the face shearing coal as it moves. The coal drops onto a belt conveyor and is transported to mine cars or conveyor belts located in the main entries. Self-advancing hydraulic jacks are set up along the face and behind the conveyor belt to support the immediate roof area. As mining progresses, the face equipment and the self-advancing jacks are moved forward allowing the roof to cave in behind the jacks.

Impacts of underground mining

The use of underground mining methods will increase capital expenditures because underground production and development is more costly than surface mining. In addition, there is a social cost expressed in health and safety of mine employees. For example, fatal accident rates for 1972 of 0.42 fatalities per million tons of underground mined coal are greater than the 0.07 fatalities per million tons mined by surface methods. There is also a higher incidence of nonfatal accidents due to roof and coal falls, fires, explosions, and problems related to dust inhalation (black-lung).

With underground mining there is less initial disturbance of the land surface, but unsupported roofs between pillars ultimately collapse due to lack of structural strength. In areas where overburden is thin, this collapse results in a lowered land surface degraded by numerous depressions and openings. Longwall mining achieves greater coal recovery and allows controlled subsidence to the point of natural stabilization which lessens the surface effects and permits use of the land surface.

Subsidence of a large area commonly destroys man-made structures. It can disrupt the ground water hydrology and surface and subsurface water recharge. It may intercept or short-circuit surface and subsurface water movement across or through the area that has subsided. Subsidence may increase vertical permeability and aquifer recharge. Subsidence also may provide increased communication between aquifers. It could also, in some localities, cause landslides or minor earthquakes.

Ground and surface waters entering active underground mines are normally pumped to the surface for disposal. It is uncertain whether acid-mine water would be a problem in the basin. Acid-mine water could drain from active and abandoned mines for long periods and cause water pollution. Acid water, if produced, is expected to be localized in a given mine or mines and not be a problem because of the relatively low concentration of pyritic sulfur in coalbeds of the Eastern Powder River Basin.

Many operations associated with underground mining, such as mine-access roads, coal handling, and processing, cause dust problems. Road dust can be minimized by hard surfacing, oiling, or chemical treatment of the road surface. Dust from coal handling and processing is abated by spray treatment at transfer points and by enclosing coal handling and processing structures. Dusting problems in live coal-storage piles can be reduced by water sprays or oiling.

Underground mining also has environmental impacts associated with drilling, blasting, alteration of ground water hydrology, product processing, and liquid effluent discharges.

Other possible environmental impacts are those associated with the creation of waste disposal areas, unsealed abandoned mine openings (inquisitive public) and abandoned mine buildings and structures.

There is a loss of coal left in pillars for support of the mine roof and in the floor and roof because of the practical limit as to the height of underground openings in coal operations. There is also a loss of coal in a bed which lies too close to another bed to be mined simultaneously. With the thick coalbeds found in the eastern Powder River Basin, the amount recovered by underground methods could be as little as six percent of the available resource.

In-situ mining

In-situ mining of coal is, at present, an experimental process which involves the fracturing of coal underground and igniting it in order to produce clean burning gas which is collected from boreholes drilled into the coalbed.

In-situ mining first requires drilling of numerous boreholes throughout the planned mining area. From these boreholes, measurements can be taken to determine orientation of coal cleats (fractures), directional permeability, directional tensile strength, point-load induced failure, and directional sonic velocity, all of which govern the directional flow properties of the coal. Next, a subsurface communication of gasses and fluids must be established by hydraulic fracturing of the coalbed, using the "sand-frac" process or similar process, which increases the permeability of the coalbed. This process basically involves the injection, under pressure, of gelled water containing sand into the coal formation thereby causing fracturing. Once the coalbed has been fractured, it is ignited in specific areas

through the boreholes. Air is injected into some of the boreholes to stimulate the burning process and the gas produced by burning is drawn off through other boreholes. Care must be taken to prevent leakage from cracks and crevices in boreholes and other areas. Any leaks will reduce gas output appreciably. Present knowledge indicates that the energy recovery levels of in-situ production are low and the amount of surface subsidence in areas of thin overburden is highly unpredictable.

For in-situ production to be a viable alternative, methods for increased recovery of volatile gases must be developed. Such increases may then allow in-situ production to compare favorably with the high recovery of surface mining.

Impacts

Impacts associated with in-situ mining would include the probable destruction of coalbed aquifers and pollution of ground water aquifers. With thin overburden, air pollution could be expected from escaping gases, and subsidence and destruction of surface values would probably occur. The many problems of containing contaminants related to underground operations are not predictable without intensive site analysis. There would be disturbance of the surface due to the construction of facilities built to process the gas produced, and chemicals, fuels, and materials used in producing gas by this method would be lost for other uses. The fuel would be low in sulfur because the sulfur produced would be in the form of hydrogen sulfide which could be removed by hot carbonate scrubbers.

Auger mining

Auger mining is a low percentage extraction method used in areas where strip mining has left an exposed coal face or where a natural coal outcrop exists. The amount of coal recovered by augering is a function of the

size of the augering equipment and the depth of auger holes. Present equipment is capable of drilling holes 150 to 200 feet in depth. If augering was the primary coal extraction method, coal production would be limited to a thin belt along the coal outcrop.

The initial step would require preparation of a working bench and roads along the outcrop. This would be accomplished by using a bulldozer and/or shovel to prepare a flat, wide area along the entire length of the outcrop to be mined. The area must be wide enough to accomodate augering equipment. All material from this preparation process would be cast to the side until it could be replaced after augering is completed.

Once the bench has been prepared, augering begins. Present equipment limits the diameter of the holes to a maximum of 84 inches. As augering proceeds along the outcrop, coal is loaded into trucks which carry it to the discharge point (plant, trains, etc.). Once the coal is removed, the spoil removed in preparing the bench can be returned, graded and reseeded to restore the area to its original condition.

Augering can also be conducted in conjunction with stripping operations. In this case, when stripping has progressed as far as economically practicable, the remaining highwall is auger mined, using the same procedure as described above. However, the bench preparation would not be necessary since the bench would be created during the strip mining operation.

Impacts

Auger mining would produce most of the impacts associated with surface mining described in Chapter V. The most important difference would be that employment of the auger mining method would result in a loss of at

least 60 percent of the coal because of the wandering characteristics of auger bits and limitations in the diameter and depths of the holes.

Alternative Reclamation Objectives

Most areas associated with mining, construction, and temporary rights-of-way are eventually abandoned to another land use. A variety of potential land uses can be considered after surface disturbance and topographic alterations have occurred. Post-mining land uses which are considered as optional alternatives within the study area are grazing, wildlife habitat, recreation, cropland, urban and commercial development, and multiple land use combinations. Methods of reclamation should be chosen with a specific land use objective in mind following mining (Table 1).

It was assumed in Chapter II that the ultimate land use objective of rehabilitation would be for livestock grazing. An analysis of the impacts is contained in Chapters VI and VIII. Grazing is included in this section to provide comparison with other alternative land uses.

Grazing

Grazing is best suited on areas having flat to gently rolling topography with suitable water reservoirs. The land surface should be improved by topsoiling, fertilizing, mulching, and mechanical treatment. Both native and introduced species of vegetation can be used successfully.

Surface soil materials must be capable of supporting vegetation to provide adequate ground cover for erosion control and some harvestable forage. The topography should vary from flat to gently rolling with no slopes steeper than 4:1, and a considerable advantage would be obtained from gentler slopes which would allow machinery to be used to redistribute topsoil and to reseed. Highwall areas should be reduced to an angle of repose that does not represent a hazard to grazing livestock. The selected revegetation species should be compatible with the soils, climate,

season of grazing use, and with adjacent native vegetation. Livestock fences and watering facilities would be installed.

Impacts

Rehabilitation of lands solely for grazing purposes would impact and limit other land uses. Wildlife habitat and recreation use would not be optimized. Fences would interfere with some species of wildlife and recreation use. A less diversified vegetation, possibly a monoculture suitable for livestock forage, would be established. This would limit wildlife diversity and would be less attractive for recreational purposes. Water impoundments for livestock would be limited in size and would have very little value for recreation or aquatic habitat. Competition would exist between some wildlife species and livestock. Wildlife populations would be reduced. Increased erosion would occur due to removal of protective vegetative cover by grazing. An increase in air and water pollution due to increased wind and water erosion would occur. Other vegetation would be trampled and the soil surface would be compacted.

Wildlife habitat

Areas to be used primarily as wildlife habitat should be reshaped to a rolling topography with slopes no steeper than 3:1. Highwalls should be reduced to the same slope to eliminate hazardous conditions. Many wildlife species prefer areas with rough or significant relief containing lakes and reservoirs. Wildlife will also use areas having other types of topography with gentler relief. The soil should be stablized by topsoiling, fertilizing, mulching, and with special structures on slopes of 3:1 or steeper to prevent erosion. Replacement of the topsoil will be necessary for reestablishment of vegetation.

A large variety of native shrubs and grasses would be planted with some establishment of trees in suitable areas. Limited areas of introduced

species would add variety to the habitat. The greater the variation in habitat and food sources, the greater variety of wildlife can be expected to repopulate the area. Sagebrush seeding would be highly desirable along with other plant varieties.

Water impoundments would be designed specifically for wildlife habitat. Stagnation of waters would not be tolerable. Highwall areas, if used to facilitate formation of lakes, would have to be fenced to protect wildlife.

Impacts

Rehabilitation of lands for wildlife habitat would shorten the time necessary for wildlife to repopulate the area. Increased steepness and roughness of topography would not permit use of the lands for some forms of recreation, urban and commercial development, and cropland use. Potential for livestock grazing would be reduced since the type of vegetation would not constitute preferred forage species. Rougher and steeper topographies would result in increased instability of surface soils. Erosion and soil movement would be increased. Heavy wildlife use could result in excessive removal of plant cover and increased soil erosion. Recreation uses, including vehicles, large numbers of people, or other high intensity uses would be limited in order to permit more sensitive wildlife species to occupy the area. Air and water quality would be reduced by increased soil erosion.

Recreation

Recreation is possible on all types of landforms, depending upon the type of activity contemplated. Access roads, trails, and plant species would be planned to be compatible with slope and soil conditions. Hazardous conditions would have to be eliminated.

As with other land uses, topsoil should be replaced on all disturbed areas and revegetated with specified grasses, shrubs, and trees conducive to maintaining stable conditions and attractive surroundings.

Water impoundments would be desirable for recreation use. These would be built to specifications that meet approval of the State Board of Health and to prevent stagnant pools from forming. Shoreline slopes should not be greater than 3:1, or they should be bermed as an additional safety measure.

Impacts

Recreation use of rehabilitated lands would result in an increase in littering and trash. Off-road vehicle use would be increased which would result in destruction of plant cover and increased erosion and compaction of soils. Aesthetics would be impacted by erosion, trails, and litter. The diversity of wildlife species and population numbers would be reduced. Wildlife species sensitive to human disturbance would be eliminated. Livestock use would be curtailed or totally absent from heavily used recreation areas. Some pollution of impounded waters would occur. Air pollution from vehicle emissions and dust would occur. Noise levels would be increased. Water impounded for recreation use would be unavailable to industry, agriculture, and other uses. This alternative could provide sorely needed opportunities in the event population growth becomes significant in the area.

Cropland

It is not generally considered a practical objective to return surface mined areas to cropland production except for small areas used for extraction of gravel or rights-of-way or other types of limited surface disturbance. Surface topography should be flat or a very gently rolling landform. Slopes should not be any steeper than 5:1. Topsoil should be stockpiled and replaced to a depth of

at least two feet over suitable overburden of sand, gravel, or porous rock. Fertilizing, mulching and mechanical seeding are necessary and irrigation highly desirable.

Impacts

Crop failures due to climatic variation and lowered soil fertility could be expected and average yields uneconomical unless irrigation is available. Erosion would be expected on dryland areas where summer fallowing is practiced and air and water quality reduced. Recreation use would be eliminated or severely restricted during parts of the year. Most cropland is seeded to a monoculture such as wheat or alfalfa, thus limiting diversity of wildlife habitat. Livestock grazing would be limited to specific seasons of the year. Economic and local demand for farm products would bear directly on this alternative.

Urban and commercial development

Urban and commercial development would be best suited to flat to gently rolling topography with lakes or reservoirs. Topsoiling would be desirable but not essential for this type of development. Fertilizer, mulch, and mechanical treatment would be needed to establish desired landscaping. Introduced grasses, shrubs, and trees would be used, including the use of water for irrigation.

Impacts

Choosing urban and commercial development following mining would exclude other land uses almost entirely. This land use option would represent a permanent change since potential for wildlife habitat, livestock grazing, and cropland production would be eliminated. Impacts from increased erosion would occur during construction operations and ambient air quality would be reduced. Increased pollution of local water ways would occur. Noise levels would be

increased. The need for community expansion in terms of alleviating congestion or increasing quality of living could dictate a high-value option for this use.

Multiple use

Multiple use or a combination of the above alternatives would provide optimization of the various uses in harmony with land capability.

Impacts of land use alternatives

The selection of post occupancy land use would be a decision of the land management agency on federal holdings and would be based on planning objectives encompassing least adverse impacts on the environment. With respect to private land, ultimate use objectives will have to be developed cooperatively with the land owner. In either case, impacts vary with the objectives chosen.

Reclamation Alternatives*	Land Use Objectives: Grazing	Wildlife	Recreation	Farming	Urban and Commercial
Topography - Landform					
1) Flat - Gently rolling	1	2	2	1	1
2) Rough - Significant relief	3	1	2	4	4
3) Highwalls (reclaimed)	3	2	3	4	3
4) Lakes and Reservoirs	1	1	1	2	1
Soil					
1) Surface with topsoil	1	1	1	1	1
2) Surface without topsoil	4	4	3	4	2
3) Rebuild soil structure	1	1	1	1	1
4) Fertilize and Mulch	1	1	1	1	2
5) Mechanical surface treatment	1	1	2	1	2
Revegetation					
1) Native species	1	1	1	4	2
2) Introduced species	2	2	2	1	2
3) Irrigation	1	2	2	1	2

*Alternatives may be selected singly or in combination.

Legend: 1 = Desirable alignment of reclamation with land use.
2 = Acceptable alignment of reclamation with land use.
3 = Undesirable alignment of reclamation with land use.
4 = Unfeasible alignment of reclamation with land use.

Table 1

Post-Mining Land Use Alternatives*

Typical Topography of the Basin

Alternate Mode of Distributions

Rather than mine and ship by railroad the predicted 150 million tons of coal per year by 1990, coal (or its energy) could be distributed by five other modes:

1. Transmission lines from mine mouth electric generating plants.
2. Pipelines for gasification plants.
3. Slurry lines from mine mouth plants.
4. Trucks.
5. Conveyor belts.

Any one of these modes with or without the railroad could possibly be adopted. All five modes would have a population impact in terms of construction personnel for transmission lines, gas lines, slurry lines, roads and conveyor belt installations. Population would peak at the height of construction activities. Community demands, recreation and other land uses would be temporarily affected by this influx of construction people. After the construction period, the number of people would be reduced to that necessary for operation and maintenance of the distribution systems. Each system will require rights-of-way of varying width and number. Impacts of coal mining described in Chapter V, of this part, will still occur.

Transmission lines

The predicted 1990 output of 150 million tons of coal would produce about 246 billion kilowatt hours and require about 25 transmission lines of 735-kv capacity to distribute this energy yield.* Powerlines would be a visual distraction on the environment and require about 23 acres per mile of

*This is based on transmission lines 600 miles long, if the lines were 300 miles long, only 15 transmission lines of 735 kv would be required.

right-of-way for each line. Installation of transmission lines have the least damaging affect to the surface environment of the various distribution systems. The only significant excavation would be for foundations of transmission line towers. However, access roads to and within the right-of-way would be required for construction and maintenance. Regular inspection of the lines could be by helicopter, but recreationist and other land users would probably make use of the access roads. Transmission lines would have no significant effect on big game migration.

Assuming that 19 transmission lines (13 to the east and 6 to the south) would be required, approximately 16,400 acres would be needed for rights-of-way. Only 2,400 acres would be disturbed by construction of the railroad and 1,100 of this would be permanently occupied.

Pipelines for Gasification Plants

If the total annual production of 150 million tons of coal were processed for gas, a large network of pipelines would be needed to distribute the gas from about 13 plants of 250 million cu. ft./day capacity using the Lurgi process. Present pipelines could possibly absorb some of this production but many new lines and pumping stations would have to be constructed to handle the large quantity of gas. Buried pipelines have a major initial impact on the surface because of the trenching necessary during installation; however, the disturbed surface can be revegetated and restored to essentially the same use as prior to installation. Pipelines require about 12 acres per mile of right-of-way. After construction and restoration, the visual impact is practically nil. Minor surface disturbances will occur occasionally to repair leaks and breaks in the lines. After construction, the impact to big game migration will be insignificant.

Assuming that 200 to 400 miles of additional pipelines within the study area are required to transport the gas, 2,400 to 4,800 acres would be temporarily disturbed. The railroad construction would temporarily disturb 2,400 acres and 1,100 acres would be permanently occupied.

Coal slurry pipeline

A detailed description of development of a coal slurry pipeline can be found in Chapter III of this part.

A coal slurry pipeline would be capable of transporting a portion of the planned coal production to a point of consumption. The proposed coal slurry pipeline for the basin would be a 38 inch pipe requiring an average right-of-way width of 100 feet. Depending on terrain to be crossed it will require a pumping station every 60 to 90 miles. The 38 inch pipeline has the capacity of transporting 25 million tons of coal per year. This is only 17 percent of the total 150 million tons annual production planned for 1990. Six of these lines would be required to handle the total coal production.

Impacts of slurry pipelines

Construction of the pipeline would require vegetative and soil disturbance on an average of 12 acres per mile of line. Each pumping station would require 30 acres. For a line of 200 miles this would mean a total of 90 acres of land removed from production for the pumping stations. Long pipelines would be required to reach markets. In addition to pumping stations, facilities required for preparation of the coal slurry would remove another 60 acres of land from production. Transporting 25 million tons of coal would require the consumptive use of 15,000 acre-feet of water per year from the basin. Construction of the pipeline would involve at a peak period 950 to 1,100 men. This would have

short-term impacts on the communities along the pipeline route. Operation of the facilities would require considerably less people.

Once buried, little evidence of the pipeline would remain except for the pumping stations. The pipeline would operate continuously. Except in the vicinity of the preparation plant and pumping stations little noise would be noticeable. Disposition of the water could create problems at the pipeline terminal unless the water is utilized in the power plant. Operation of the preparation plant would require 58 megawatts of electrical energy.

The probability of a pipeline break or leakage always exists. As the line would cross underneath many rivers and streams, there is a high potential for damaging spillage with resulting water and land pollution. Any spillage or leakage into water courses will result in damage to aquatic life, aesthetics and recreation values.

About 180 miles of pipeline would be needed within the study area, temporarily disturbing 2,160 acres of land, while the railroad construction would disturb 2,400 acres and permanently occupy 1,100 acres. Consumptive use of 90,000 acre-feet of water per year would also be required.

<u>Truck transportation</u>

The feasibility of transporting coal by truck is assumed to be limited to short hauls such as between mine and power plants, railroad or slurry pipeline. Truck size would be limited and a great number of trucks required. The maximum gross weight for trucks on Wyoming highways is 79,900 pounds or 39.95 tons. Truck size would have to be within the range of 30 to 35 tons. Over 79,900 pounds, a special permit is required and a special use tax assessed.

Assuming that all proposed coal production would require transportation by truck from mines to other facilities, about 5 million 30-ton or 4.25 million 35-ton truckloads would be required to haul the predicted yearly output of 150 million tons of coal by 1990. If 100-ton trucks were used, 1.5 million loads would be required. Roads capable of handling this volume do not exist in the area. Heavy truck traffic would disrupt normal traffic, create hazards to humans and wildlife, and consume vast amounts of scarce petroleum products.

If larger trucks were used to haul coal, construction of special facilities and highways would be required. Volume of traffic would dictate need for multiple lane highways. Such highways would be a physical barrier to wildlife similar to a railroad. Construction would require earthmoving and structures similar to that of a railroad. Highway grade tolerances are greater than those for railroads and would require less extensive cutting and filling to achieve acceptable grades. Depending on highway specifications, the land surface occupied could be equal to or greater than the railroad. Side roads would have to be extended to mine sites.

Frequency of truck usage would result in constant high noise level; in open country noise carries for considerable distances since there are no barriers to absorb sound. Truck exhaust emissions would affect air quality. A large work force would be needed to operate a truck transportation system including drivers and service personnel. Storage yards, repair facilities and terminal facilities would also be required. These would occupy large areas, and spread environmental impacts over a wider region.

Conveyor-belt systems

Belt conveyors can be used as an alternative transportation method to railroads. Expertise is sufficiently advanced to assure technically sound

construction and performance of single or multiple flight belt conveyors for coal transport. A single belt conveyor capable of transporting the large amounts of coal required (150 million tons per year by 1990) over the distances specified has never been constructed. Single conveyors capable of transporting as much as 20,000 tons per hour of coal are under design study. A conveyor of this size would have to be operated on a 24-hour basis for 313 days to haul the estimated yearly production by 1990.

Multiple conveyors capable of transporting required tonnages can be constructed, but never have been for the distance involved. Thus, belt conveyor transport systems designed to substitute for rail transport are a new and experimental system not to be considered lightly nor undertaken without extensive design and pilot work.

Belt conveyor systems would more likely be used to substitute for rail spurs to single mining operations rather than substitute for the rail link between Gillette and Douglas, Wyoming.

Belt conveyors offer great design flexibility and economy in those instances where distance and quantity requirements are well known and are expected to remain relatively fixed. In the Eastern Powder River Basin, coal production is expected to increase steadily and become large in the next ten years, thus requiring constant expansion and improvement of any envisioned belt system. On the other hand, the rail system offers less design flexibility but is more suitable than belt systems to surge loading and peaking transport requirements.

A belt conveyor would be subject to belt lift by wind and would create quantities of coal dust downwind. To decrease dusting, the entire length of the system would be necessarily hooded or guarded against wind.

This would add to the visibility of the structure and increase the impact on wildlife and aesthetics of the area. Electric motors are normally used to power the belts. They would be located at frequent intervals along the lines requiring service roads, electric transmission lines and other service facilities.

Extensive land areas would be required at loading points and at end points where coal is to be transferred to other transport systems such as rail. At these transfer points, large surge capacity would be necessary because the belt system would be transporting well over 100 million tons of coal per year at a relatively constant rate for subsequent movement.

Impacts

Construction of a conveyor system would cause impacts similar to railroad construction.

Alternative to Private Development

The federally owned coal reserves and resources of the area would be developed, mined, and marketed by a federal organization. Private surface owners and existing lessees of federal coal would necessarily be compensated in those areas to be developed. This federal mining would require enabling legislation by Congress before implementation. The possibility that Congress would enact the necessary legislation is speculative. Any federally owned or controlled mining organization would likely strive for efficiencies in production comparable to existing companies under a free-enterprise system. Machinery, labor requirements, and scales of production would be similar to most of the existing and proposed mining operations.

Impacts

Impacts could be about the same as those resulting from the proposed actions unless central authority was broadly exercised from a single managerial point.

Under a strong central organization, such as a federal coal agency with responsibility for the coal resource, there would be greater opportunity for centralized research capability, more conservation of the lands and their resources on a regional basis, and better zoning and legal control of land within Campbell and Converse Counties.

The total impact through time from the mining of coal in the Powder River Basin indicated in Chapter V of this part might thus be partially lessened by central control of the coal basin. An example of one such agency, although directed to a different function, is the Tennessee Valley Authority.

Alternate Utilization Methods

Two alternate methods to utilize coal near the mines have been proposed: steam powered electric generating plants and gasification plants. Two electric generating plants are currently operating within the study area; one is scheduled for expansion. Two additional power plants, both water-cooled with a minimum size of 500-megawatts are assumed by 1990. One gasification plant has been proposed; another is assumed by 1985. Descriptions of electric generating and gasification processes are found in Chapter II.

Three onsite generating plants with a rated output of 10,000 megawatts each would be required to utilize the assumed coal production of 150 million tons in 1990. Proportionately, six plants of a 5,000 megawatt output would consume the same amount of coal. Additional transmission lines would be needed. Thirteen gasification plants would be required, with supporting facilities, to utilize 150 million tons of coal mined in 1990. Pipelines or other facilities would be needed to import water and pipelines would be used to export the synthetic gas.

The impacts of coal mining would still occur, however impacts not occuring if these alternatives are utilized would be those associated with railroad construction.

Environmental impacts

Onsite power generation

The local environmental impacts that would result from onsite power generation would be: 1) degradation of air quality by stack emissions; 2) land-use problems related to ash disposal; 3) noise from the generating station; 4) the large quantity of water needed (approximately eleven acre-feet per year for each megawatt of power produced; 5) impacts on aesthetics and recreation use by the generating station, miles of transmission lines and support facilities;

6) dust related to coal handling, processing, and ash disposal; 7) loss of land used by the generating station and support facilities (1,000 to 10,000 acres for each power generating station and approximately 23 acres per mile for a 345-kv transmission line); 8) increased employment and related economic benefits in the region; and 9) increased impact on the social-economic conditions.

Generating plants alone would require 30,000 acres, while the railroad would permanently occupy 1,100 acres. Trains would emit fewer pollutants than the generating plants and require very little water.

Gasification

Like natural gas, the products of coal gasification (synthetic natural gas) are clean-burning fuels. As a result, pollution control features are an integral part of the manufacturing process.

Environmental problems common to all ventures using coal for gasification are water consumption and contamination, air pollution from sulfur components and particulate matter, and possible noise and site pollution.

Plant operation, including handling and transporting the coal to the process site and converting the coal to gas, will involve large quantities of coal. Major emissions that must be controlled are sulfur and nitrogen oxides, bottom ash, slag, and fly ash. Since coal conversion plants are located near strip mines, ash and slag from the process can be returned to the open cuts, and the ground restored in accordance with environmental considerations. Technology for controlling sulfur and nitrogen oxides from such plants is under development.

To illustrate the order of magnitude of the major emissions that would have to be handled from a commercial coal-to-pipeline gas plant, the Federal Power Commission's National Gas Survey gave the following estimates, based on a

plant producing 250 million standard cubic feet per day of pipeline gas from coal with 3.7 percent sulfur:

Table 2

	Short Tons Per Day
Sulfur (mainly as hydrogen sulfide)	336 - 504
Ammonia	112 - 168
Phenols	11 - 78
Benzene	56 - 336
Oil and tars	trace to 448
Ash (based on coal with 10% ash)	1,680

Plant operation requires large quantities of water for cooling and for scrubbing gases, perhaps as high as 30 million gallons per day for a completely water-cooled plant producing 250 million cubic feet of synthetic gas per day. The discharge of contaminants such as phenols, benzene, oil and tars must be controlled by use of purification systems integrated into the facility or by recirculation of waste to extinction. Process waste solids such as spent dolomite, in the case of the CO_2 acceptor process, may present problems of surface water contamination.

This one plant site would require approximately 1,000 acres of land which would be removed from any other type of production for the life of the project.

Waste solids such as char, granulated extract, and powdered sulfur must also be disposed of. Much of the solid waste could be used as fill in trenches left by surface mining operations prior to recontouring of the land to match its original surroundings.

Construction employment, with a peak of 2,500 to 3,000 employees, could significantly impact the local communities. Permanent employment would be at a lower level, 600-800 people, but could still cause serious impacts on the local social and economic conditions.

Secondary impacts could result from the production of by-products associated with the gasification process. By-products could include; 30-40,000 tons of sulfur per year, and 100,000 tons per year of ammonia and phenols. These by-products, would require storage areas and facilities or disposal systems.

About 13,000 acres would be occupied by gasification plants while the railroad would occupy 1,100 acres. Less pollutants would be released in the area by rail transportation, and little water is required for operation of diesel trains.

All impacts from coal mining would remain the same as described in Chapter V, of this part except part of the void left from removing about 70 feet of coal could be partially filled by the ash. Assuming that all of the coal would be utilized at mine mouth for generating or gasification plants, the need for a new railroad and expansion construction of new plants elsewhere would be eliminated.

Alternative Sources of Energy

This section describes and analyzes alternative sources and forms of energy. Traditional sources such as oil and gas and the more exotic new energy sources such as magnetohydrodynamics, solar, tidal, etc., are examined to the extent present technological development permits. To replace Eastern Powder River coal at projected development levels would require annual energy equivalent of 1.5 quadrillion Btu (1 quadrillion = 1,000,000,000,000,000) by 1980, 2.0 quadrillion Btu by 1985 and 2.6 quadrillion Btu by 1990. It is unlikely that any one source could be expected to furnish this quantity of energy. The final section examines briefly the outlook for a combination of energy sources other than Eastern Powder River coal.

Using the Btu as a basis for converting other energy materials to the equivalent of coal production from the basin for the three time periods, Table 3 indicates a scale of quantities from five energy sources that would compare with basin development.

Production from the Outer Continental Shelf (OCS)

This alternative would require increased exploration, development, and production of crude oil from offshore areas. Supplies of petroleum equal to all, or an appreciable part of the projected coal production from the Eastern Powder River Coal Basin of Wyoming (estimated at 1,543 million short tons from 1974 to 1990), would have to be developed and produced in addition to petroleum that would otherwise be produced from OCS resources under the present leasing schedule during the same time frame. About 4,567 million barrels of oil or an average of 268.6 million barrels of oil per year would be needed to provide the equivalent energy (Table 3). This alternative is not immediately feasible because it would require the conversion of two power plants that are built to use solid fossil fuel to two capable of utilizing petroleum. Additionally, it is questionable that the increased oil could be immediately produced, refined, and transported to the power plant sites without seriously disrupting the operations of other users. This alternative would also require the increased production of crude oil from offshore areas to provide fuel for the numerous power plants planning on supplies of coal from Eastern Powder River Coal Basin of Wyoming.

In his April 18, 1973 Energy Message, the President announced that he had directed the Secretary of the Interior to take steps to triple the acreage leased on the OCS for drilling for oil and gas by 1979. In response to the President's Energy Message, Rogers C.B. Morton, Secretary of the Department of the Interior, issued a proposed schedule of provisional OCS leasing on July 11, 1973, calling for three sales per year of as many as one million acres each.

The President also announced that leasing would begin in new frontier areas, including areas beyond the 200-meter isobath, and beyond the Channel Islands in the Pacific if the environmental impact statements indicate it can be

Table 3

Energy Yields of Various Fuels

Energy Sources	Conversion Rates - 1 Ton Coal	Cumulative Projections Based on Coal Production		
Eastern Powder River Basin Coal Production	N.A.	1980 296 MM Tons	1985 858 MM Tons	1990 1543 MM Tons
LNG*	3.74 Bbl	1,107 MMbbl	3,209 MMBbl	5,720 MMBbl
Nat. Gas	16.700 Mcf	5 MMcf	14 MMcf	26 MMcf
Petroleum	2.96 Bbl	876 MMbbl	2,540 MMBbl	4,567 MMBbl
Oil Shale**	4.92 Tons	1,456 MM Tons	4,221 MM Tons	7,592 MM Tons
Uranium***	0.08 lbs	23.7 MMlbs	68.6 MMlbs	123.4 MMlbs.

Fuel	Energy Yield (Btu per Unit)
Coal	17.2 million Btu per short ton (8,600 per pound)
LNG*	4.6 million Btu per barrel
Natural Gas	1,032 Btu per standard cubic foot (SCF)
Petroleum	5.8 million Btu per barrel
Oil Shale**	3.5 million Btu per ton
Uranium***	214 million Btu per lb of U_3O_8 (Coal Age Apr. 74)

*LNG = Liquified Natural Gas
**Based on a production standard of 25 gallons of shale oil per ton
***Yield is dependent on thermal efficiency and load factors of reactor systems.

done safely. He directed the Council on Environmental Quality, in cooperation with the National Academy of Sciences and other government agencies, to complete studies within one year on the environmental suitability of drilling on the Atlantic OCS and the Gulf of Alaska. By 1985, this accelerated OCS leasing schedule could increase annual production by approximately 1.5 billion barrels of oil which is approximately 16 percent of our total projected national energy requirements, assuming that production from current leases is maintained.

The offshore areas of the United States are estimated to contain resources of 186 billion barrels of crude oil and over 844 Tcf (trillion cubic feet) of natural gas recoverable with existing technology. These amounts represent approximately 40 percent of the nation's total undiscovered oil and gas resources and offer especially promising opportunities for discovery because many onshore areas thought to be geologically favorable for oil and gas have already been explored and developed.

The Federal Government has leased OCS lands since 1954. Currently, leases on the OCS are producing more than 400 million barrels of oil and about 3 Tcf of natural gas annually.

In 1969, after problems with oil leaking in the Santa Barbara Channel, regulations of the Department of the Interior governing leasing and operations by lessees on the OCS were extensively revised and strengthened. Since then, a continuing effort has been made to improve safety and pollution control standards for a wide range of operations including drilling procedures, well abandonments, well completion procedures, waste disposal, and the installation and operations of platforms and pipelines. Inspection procedures have been standardized and a statistical basis for inspection strategy has been developed. The OCS field inspection staff has been tripled since 1969. Six full-time helicopters are in use and a radio communication system has been installed. The revisions and

strengthening of OCS operating standards and the increase in surveillance personnel have resulted in a marked improvement in OCS operations with regard to oil spills. There were no major oil spills in 1972. Minor oil spills in 1972 were reduced by 45 percent from 1971.

Changes that could stimulate additional development of resources include price increases, subsidies, tax benefits, and changes in leasing procedures. The cost and effectiveness of such changes are largely unpredictable. The timeliness and the volumes of increased supplies of oil and gas that would result from increased incentives are also unpredictable. It is estimated that the time lag between leasing and production in the frontier areas will be as long as 12 years.

Geophysical exploration phase

The prime objective of structural analysis of the continental shelf is to locate geologic structures, such as local upwarping of the sediments, which are favorable for the accumulation of petroleum. A knowledge of the subsurface geology is also necessary to detect near surface conditions, such as recent faulting or high pressure zones, which are potential hazards to exploration and production operations.

In seismic exploration a ship travels along a predetermined path towing signal generating and recording equipment. The energy source generates a series of small amplitude seismic pulses that travel at thousands of feet per second through the water and sediments below where they are reflected and refracted by the underlying strata. An array of sensitive hydrophones towed by the vessel detects incoming seismic waves which are recorded on magnetic tape, processed, and displayed as vertical cross sections. By assembling cross sections run in

various directions, a three-dimensional picture can be constructed indicating location, size, and form of geologic structures favorable for oil and gas accumulation.

In the early years of offshore exploration, explosive charges detonated in the water layer provided the energy source for seismic waves. Safer equipment and methods such as vibrator systems, sparkers, air guns, and gas guns have evolved within the last five years and now account for well over 95 percent of marine seismic activity.

Exploratory drilling phase

Most offshore exploratory drilling is done by mobile drilling rigs that can be moved from one location to another with relative ease. These mobile rigs include those that are bottom-supported while drilling (jack-ups) and those floating rigs that are held in position over the site by anchors (semi-submersibles). Shallow (less than 300 feet) water exploratory drilling is commonly carried out using a "jack-up" type drilling rig, while deeper waters require the use of semi-submersible rigs.

The drilling process itself is virtually the same as onshore drilling described in the previous onshore section but with a few modifications. The drill pipe is run through a casing called a riser that extends from the floor of the mobile rig to the ocean floor. Drilling mud that has traveled down inside the drill pipe returns to the rig inside the riser. Well casing is set as drilling proceeds. This prevents unconsolidated or loosely-consolidated zones from caving in and plugging the hole. Unconsolidated zones are a common occurrence offshore Louisiana.

Whereas onshore drilling mud is collected in pits or in mud tanks at the drill site, offshore drilling mud is also collected, stored, and reused.

Drill cuttings, however, are cleaned of oil and released to settle on the ocean floor.

Should a well be what is termed a "dry hole," it is plugged with cement as dry holes onshore are plugged. The casing is cut off at least 15 feet below the mud line, all obstructions are removed, and the bottom is dragged to be sure no obstructions remain. If the well shows commercial quantities of hydrocarbons, then decisions must be made about development of the reservoir, setting the platform, drilling the production wells, and getting the production on stream.

Production and workover phase

Offshore production operations are usually conducted on fixed, bottom-founded, water surface-piercing platforms. The platform is generally fabricated in two pieces at a shore-based facility according to design specifications of the petroleum producers. The two component pieces, the supporting structure and the upper, horizontal platform, are then towed or barged to the installation site. The structure is emplaced by controlled flooding and sinking of the lower end of the tubular legs. The horizontal platform is then lifted into place on top of the tower and welded to it. The drilling derrick, rig power plants, generators, living quarters, storage sheds and other components, constructed in modular form, are added to the platform, and production well drilling commences. The sequences of drilling operations for production wells is essentially the same as for exploratory wells.

Wells usually are produced through tubing placed inside the final or production string of casing. During tubing installation, blowout preventers remain in use to insure control of the well. A system of in-tubing safety valves, plus other casing and tubing valves at the surface or seafloor, is installed to control well flow. Actuation is usually at the producing platform.

A wellhead, consisting of several redundant control valves, is installed at the platform cellar deck level and subsurface safety valves are installed at depths varying from a few hundred to several thousand feet in the tubing string. Of major concern in the operation and control of every production platform are the downhole control devices. Production tubing is fitted with one or more safety valves that are installed and located at least 100 feet below the mud line or seafloor. In the past, velocity choke valves designed to shut off production when the flow rate exceeds predetermined limits have been used. Such valves should close if surface equipment failure results in an excessive flow through the tubing. These chokes are particularly susceptible to failure from internal erosion in areas where sand is produced along with the oil and gas.

Certain types of fail-safe valves do not depend on the velocity of well fluids for actuation but are held open by hydraulic or other fluid pressure applied from the surface. Release of this pressure by a control signal, or by an accident, causes them to close immediately. Their use will increase costs significantly, but the need for more reliable valves has been shown by recent incidents in the Gulf of Mexico and elsewhere.

Produced formation water

The waters associated with oil and gas pools which are frequently produced along with the oil and gas are called formation waters. The lower edge or boundary of most oil and gas pools is marked by an oil-water or gas-water contact. In some pools, water is produced with the oil in early stages of production whereas, in others, little water comes up with the oil.

Most formation waters produced are brines characterized by an abundance of chlorides, mostly sodium chloride, and have concentrations of dissolved solids several times greater than that of sea water. The total amount of mineral matter

commonly found dissolved in oil-field waters ranges from a few parts per million (ppm), nearly fresh water, to approximately 300,000 ppm, a heavy brine.

Formation water produced offshore can be treated to remove entrained oil and discharged off the platforms into the sea, it can be piped to shore for treatment, or it can be reinjected into subsurface formations for the purpose of maintaining good reservoir pressure.

Solid waste disposal

All solid waste accumulating from daily drilling and production operations is collected in large containers constructed of heavy grating. To reduce the bulk before transfer to shore, wastes are sometimes compacted in burn baskets suspended from the platform and burned. Ashes are allowed to fall into the water. Non-combustible solids are then loaded into service boats for transfer to shore where they are emptied into sanitary landfills.

Workover operations

Since petroleum production involves the handling of flammable fluids under pressure, the safety systems control is of utmost importance to preclude hazardous conditions. Nowhere is this hazard greater than during workover or remedial operations on a well in order to improve its production rate or to replace faulty downhole equipment. Since workover operations are potentially hazardous, they must be planned carefully, both to keep wells from getting out of control and to prevent or minimize the release of oil to the environment. To reduce pollution, specially treated salt water that can be weighted with various materials is used for hydrostatic control when re-entering the wells in wire-line or swabbing operations.

To increase production, acid or other fluid and suspended particulate matter may be pumped through the wellbore into producing formations. The spent

acid returns up the well when production is resumed and is handled as are other fluids from the well. Oil and water contaminated with the acid are disposed of ashore.

Sand produced along with the well fluids can cause wells periodically to plug, or "sand up," and must be removed. Other procedures to increase productivity and oil recovery include the injection of high-pressure steam, water, and/or gas. The water used for this purpose may be taken from the ocean or from formation water. Contaminated water may be reinjected into formations, taking suitable precautions to insure that fresh water aquifers will not be contaminated by oil or salt water. Gas produced from the well may be reinjected for pressure maintenance where feasible or piped to shore for sale.

From the safety standpoint, completion and workover operations must be carefully conducted; it is their critical nature that, in all likelihood, makes these operations safer than they otherwise might be. Operators of swabbing and wire-line units are well aware of the hazardous nature of their work and are extremely cautious. Despite the potential hazard, safety records during wire-line and swabbing unit work are excellent.

Construction and maintenance of pipelines

After estimates of producible oil and gas have been made, plans for pipeline construction are formulated. Pipelines laid offshore are fabricated by welding sections together on a barge while simultaneously moving the barge forward and allowing the completed expanse of pipeline to sag downward and lay on the bottom. In nearshore areas, if space permits, pipelines are welded together on the beach and the completed string pulled out to sea by a workboat.

In depths under 200 feet, present OCS administrative procedures require burial of the pipeline. Burial is effected by jetting sediment away from

underneath the pipe and allowing it to sink into the resulting trench. Over a period of time, settling and reworking of sediment by underwater currents buries the pipeline.

Pipelines near and crossing the shore are buried deeply enough to avoid exposure by storm-associated beach erosion. From shore the pipeline construction is extended toward a storage facility, gas processing facility, interstate gas line, or a major existing pipeline system. Where a pipeline crosses firm soil or sand, it is buried by entrenching and backfilling. In other areas the pipeline is buried by jetting-out around the pipeline. In the saturated coastal marshes, sections of the pipeline are usually floated through a narrow ditch, called a shove-ditch, welded together, sunk, and buried by backfill.

To prevent corrosion, most pipelines are carefully coated with such materials as epoxy compounds or thick asphaltic mastic. If mechanical damage seems likely during installation, these, in turn, are covered with a layer of dense concrete. The lines are protected from electrolysis by both impressed-current systems and by sacrificial anodes (zinc is commonly used).

Pipelines are also commonly equipped with a number of redundant systems to control flow and detect small leaks. On larger platforms a control center, from which all valves can be operated by remote control and which gives constant communication with other points on the line, is manned 24 hours a day. Line pressure and flow rate sensors linked to automatic shutdown devices cut off all flow in the event of a leak. Block valves and check valves can isolate a leaking section of a pipe quickly. In addition, the lines are inspected as appropriate by submersibles (small submarines), divers or other methods.

Offshore pipelines can be repaired by divers, although with much expense and difficulty. Methods of repair using submersibles with mechanical arms and special tools are under study and nearing the point of practical demonstration.

Terminations of offshore oil and gas operations

When the reservoir has been depleted to a level where it cannot be profitably produced, operations are terminated. The production platform is removed and the wells are plugged with cement; the casing is severed at least 15 feet below the mud line and all obstructions removed. All that remains is the pipeline system. Frequently, major trunklines can be used for future oil and gas production from adjacent areas, but smaller spur lines are abandoned in place.

Special considerations beyond 200 meters

There is, as yet, no production in water depths greater than 200 meters (656 feet); however, there may be extensive reserves at greater depths. Leasing beyond 200 meters was called for in the President's Energy Message of April 1973.

Deeper waters will require new techniques such as submerged production systems secured to the bottom of the sea. Each such system would include a cluster of wells drilled directionally from floating rigs. The entire underwater operation involves advanced technology with electronics to monitor and "instruct" each unit, hydraulics to open and close valves, and safety devices that will automatically close off any part of the system that malfunctions. If a malfunction should occur, it might be extremely difficult to correct.

Resource base

Estimates of a resource base involve quantifying the amount of mineral resource in both known areas, for which data are plentiful, and unknown areas, for which data are scarce. Table 4 shows estimates by the U.S. Geological Survey as of March 2, 1973, on the resource base of the U.S. offshore oil and gas.

Table 4

U.S. Oil and Gas Reserves and Resources
(Oil* in billions of barrels; gas in trillions of cubic feet)

	Proved Reserves		Recoverable Resources**	
Offshore***	Oil	Gas	Oil	Gas
Total	5.84	38.8	201.2	1,077.2
Alaska	--	--	62.0	280.0
Pacific	2.3	2.0	15.7	171.0
Gulf of Mexico	3.54	36.8	75.5	406.2
Atlantic	--	--	48.0	220.0

*Includes natural gas liquids.
**Does not include proved reserves.
***Includes shelf and slope to 2,500-meter depth.

Proved reserves are those calculated from known parameters at the wellhead while recoverable reserves include all other known oil and gas resources, less that amount which cannot be recovered. Recoverable reserve figures are derived from a volumetric measure of sediment and from the best geologic information available.

For comparison with the Geological Survey estimates given previously, the National Petroleum Council's estimate of oil reserves and of natural gas reserves is presented in Table 5.

Table 5

National Petroleum Council's Estimates
of Oil in Place
(oil in billions of barrels)

Offshore	Oil in Place	Oil Discovered as of 1/1/71	Oil Remaining to be Discovered
Total	176.5	16.3	160.2
Alaska	73.9	2.9	71.0
Pacific	49.6	1.9	47.7
Gulf of Mexico	38.6	11.5	27.1
Atlantic	14.4	0.0	14.4

Note that oil remaining to be discovered is not the same as "Recoverable Resources" in Table 4. The percentage of oil in place that can be recovered varies from reservoir to reservoir depending on individual reservoir conditions, and recovery factors cover a wide range of values. NPC estimates presented here are intended as merely a general comparison with USGS estimates. It can be seen that the Geological Survey estimates are considerably higher than NPC estimates for the Gulf of Mexico and the Atlantic Coast but considerably lower for Alaska and the Pacific Coast.

Table 6

National Petroleum Council's Estimates
of Gas in Place
(gas in trillion of cu.ft.)

Offshore	Gas in Place	Gas Discovered as of 1/1/71	Gas Remaining to be Discovered
Total	537.5	51.0	486.5
Alaska	277.4	5.1	272.3
Pacific	3.8	0.5	3.3
Gulf of Mexico	201.8	45.4	156.4
Atlantic	54.5	0.0	54.5

The differences between NPC gas estimates and USGS gas estimates are even more dramatic than for oil. Such variations may indicate the magnitude of "unknowns" involved in estimating supplies of oil and gas.

Economic considerations

In 1972 federal OCS production amounted to 412 million barrels of oil and condensate and 3 trillion cubic feet of gas which is equivalent to 5520 x 10^{12} Btu. Supplies of oil and gas are being produced from state offshore areas, particularly in Alaska where 64 million barrels of oil and 75 billion cubic feet of gas were produced in 1972, 100 percent of which were produced from state-owned areas. California, Louisiana, and Texas also have produced considerable amounts of oil and gas from state offshore areas. Production of oil and condensate and gas from offshore leases decreased in calendar year 1972. For this period the total offshore (state and federal) production of oil and condensate represented about 16 percent and gas represented about 15 percent of the total U.S. production, respectively. About 12 percent of the U.S. production of oil and condensate and more than 13 percent of the gas came from the federal OCS.

Leasing in frontier areas shows greatest promise for increasing our oil and gas supplies, but it may be noted here that frontier areas may require lead times of five years and longer between leasing and production.

Prior to any decision to lease OCS lands in the Gulf of Alaska and Mid-Atlantic areas, broad planning studies of the environment, natural resources, economics and other regional factors must be made available and carefully analyzed. Until the results of the studies are fully evaluated, leasing programs can not be implemented. In addition, the question of respective federal and state OCS jurisdiction in many offshore areas is currently in litigation. Until these issues are resolved, leasing action will be delayed if not cancelled.

The continental shelf of the U.S. measures 875,000 square miles or about 560 million acres and is relatively undeveloped. Of this area, 290,000 square miles or about 186 million acres are in the Gulf of Mexico, offshore Atlantic and offshore Pacific. As of Dec. 31, 1972, approximately 2.3 percent of these 186 million acres, or 4.3 million acres, were under lease. Also, as of this date there were 9,420 producible oil and gas zones; there were 1,963 fixed platforms in place including single and multi-well structures; and there were 6,000 miles of oil and gas pipelines in operation.

In the Gulf of Mexico, production platforms have been installed in water depths of up to 373 feet and drilling has been conducted in water depths in excess of 500 feet at a distance of 125 miles from shore. In the Santa Barbara Channel, production platforms have been installed in water depths of 193 feet and drilling has been accomplished in water depths of 1,497 feet. During the calendar year 1972, there were 846 new wells started and 486 completions in the federal OCS. The inevitable move into deeper water will impose greater capital needs and a consequent need for more rapid payouts than the usual 12 to 16 years now pertaining in the Gulf of Mexico.

Mobile offshore rigs and their costs include jack-ups ($9 million), drillships ($12 million), and semi-submersibles ($20 million). There are 50 or 60 semi-submersibles, jack-ups, and drillships now being built representing a cost of about $500 million. It may be noted, however, that many of these rigs are destined for foreign operations. It is estimated that the move from depths less than 200 meters to 1,000-foot depths may double exploration costs and triple development drilling costs. It is evident, then, why the deep water fields must be very large to be economically exploitable. Jack-ups are generally rated for water depths less than 250 feet; the cost for such equipment for 400 feet of water is estimated at $17-19 million. The principal constraints to lease scheduling imposed by equipment in the near future, however, are not costs but rig availability for the types of exploratory drilling that may be required. As of April 1973 on the state and federal OCS there were 60 working and four idle mobile offshore rigs in Louisiana and three working rigs and one idle in Texas for a total of 63 working and five idle. Exploration in California is presently at a standstill. With a reduction in U.S. OCS operations there has been movement of mobile rigs to foreign operations. At the present time, trained manpower for offshore rig operations is in short supply. The 50 rigs under construction will require 2,500 personnel over a period of about 18 months. This number of personnel is not presently available nor are there any schools for training them. Many companies carry extra manpower for training purposes, but the need for extensive training is evident in that 86% of accidents result from unsafe acts rather than from equipment failure. Lack of manpower is not expected to constrain OCS activity although the lack of trained manpower may reduce efficiency.

As operations move to deeper waters and more hazardous physical environments, equipment, and data needs will increase. For specific areas, more

detailed physical and climatic information will be needed such as wave height, wind force, and storm data. For the short-term, traditional equipment will be utilized until innovative equipment is developed. Equipment availability and development depends to a large extent on the establishment and maintenance of a progressive lease schedule which will allow lead time for technologic developments needed for exploitation.

Environmental impact

The development and production activity of OCS leasing will result in a variety of impacts on the natural environment, on other resource uses, on air and water quality, on land use patterns, on the social order, and on the economy. Some harmful impacts are the unavoidable result of routine operations while others are caused by occasional human error. Still other impacts are avoidable and can be controlled or avoided by safe operating practices and by regulations.

Impact on biota of the open sea

Except for the impact resulting from pipeline laying across the beach and through the coastal wetlands, most impacts resulting from OCS leasing affect the plants and animals of the open sea. Impacts in the open sea ecosystem will result from accidental loss of debris, discharge of drill cuttings, sand, drilling fluids, the burial of pipelines, and the accidental spillage of oil or toxic materials.

Impacts on pelagic marine life

Pelagic marine life includes a broad spectrum of organisms from all trophic levels and includes the phytoplankton, zooplankton, nekton (euphausids, shrimp, fish, squid, and marine mammals), and pelagic seabirds.

Impacts that may be anticipated to have an effect on plankton will result from accidental spills of oil (and associated use of emulsifiers) and other toxic materials, discharge of drilling fluids and formation waters, and burial of pipelines.

After an oil spill has occurred, oil which has not evaporated, been carried ashore, or cleaned up will be dispersed as minute droplets in the water; it may damage marine organisms and enter the marine food chain.

Little information is known concerning the effect of large spills of crude oil on the zooplankton. Huford (1971) cites one experiment which showed accelerated death of zooplankton exposed to diesel oil (0.1% for 5 to 60 minutes) as compared to non-exposed zooplankton. Zooplankton have been observed to ingest spilled Bunker C oil particles, however, with no apparent effect.

Small spills of fractions of a barrel to 50 barrels probably occur on the order of a thousand times per year in the Gulf of Mexico. It is difficult to determine potential impact from chronic, low-level spillage. A few scientists have offered cautious speculation. A pessimistic view is taken by Blumer (1969) who has stated:

> ". . . we are rather ignorant about long-term and low-level effects of crude oil pollution. I fear that these may well be far more serious and long lasting than the more obvious short-term effects."

Blumer then points out that hydrocarbons are taken up into the food chain and can become concentrated in marine species used by man for food. He states:

> "One consequence will be the incorporation into food of materials which produce undesirable flavor. A far more serious effect is the potential accumulation in human food of long-term poisons derived from crude oil, for instance of carcinogenic compounds."

Blumer also cautions that low-level pollution may damage the marine ecology by masking natural chemical sex attractants, thus interfering with chemical food sensing and enemy repulsion.

A somewhat less pessimistic view is taken by St. Amant who states:

> "Chronic pollution from offshore production sites represents an unknown factor. Daily drips and loss of small amounts of oil or other chemicals overboard do not appear to generate ecological problems because of the relative immensity of the water column. Whether such sublethal pollution will eventually accumulate and cause environmental degradation is yet to be determined. Because of this unknown factor, significant effort should be made to prevent low-level pollution."

The regular discharge of formation waters, "brines," could have a severe but extremely localized impact on plankton. Although only traces of entrained oil remain, formation waters contain a heavy concentration of dissolved salts and are devoid of dissolved oxygen. It could be anticipated that the release of this water would result in a plume trailing away from the point of discharge in the direction of the current with a core of perhaps a few feet in diameter and tens of feet in length that would be harmful or lethal to the plankton. Physiological stress would probably result from an osmotic imbalance (cells losing water to surrounding brine) and low dissolved oxygen leading to suffocation.

The remaining impacts on plankton will also be extemely localized and are all related to increased turbidity caused by the discharge of drilling fluids and drill cuttings and the jetting of sediments during underwater pipeline burial. The effect of this turbidity on a given parcel of water usually lasts a few hours at the most. The physiological effect would be to curtail the penetration of sunlight and, therefore, depress synthesis by phytoplankton.

Nekton include all marine animals which are active swimmers and are able to migrate freely over considerable distances. This mobility, combined with

their ability to sense irritation and their natural escape and avoidance behavior, enables them to flee localized adverse conditions. Therefore, the only significant impact that members of the nekton could suffer would result from a massive oil spill.

No information has been found on the effect of spilled oil on members of the nekton other than fish. Findings from laboratory experiments cannot be easily applied to oil spills in the ocean. Although the potential for damage to nekton is clear, the scope of actual impact remains unknown.

In the past, the injury and death of thousands of seabirds has been the most obvious impact of massive oil spills. The insulating properties of oil-clogged plumage are greatly reduced, resulting in heat loss. Ingestion of oil can cause a variety of pathological conditions. Feeding may drop, causing fat reserves to be exhausted. Indirect impacts could include loss of habitat and nesting areas due to installation of onshore facilities.

Impact on benthic marine life

Environmental impacts which may be expected to affect benthic life adversely will result from the discharge of drill cuttings, accidental spillage of oil (and associated use of emulsifiers) and other toxic materials, and the burial of newly constructed pipelines.

Spilled oil which has not been evaporated, cleaned up, or stranded on a beach, after being dispersed into the water as droplets, adheres to particulate matter and sinks to the bottom where it comes into direct contact with the benthos. Studies of the effects of oil on benthos have yielded only tentative and qualified conclusions. In the Arrow spill study (Bedford Institute 1970) lobsters appeared to be clean and normal in behavior. Scallops taken near heavily oiled beaches were cooked and eaten and had no oily taste, but chemical

analysis of scallops, along with periwinkles, sea urchins, and other bottom dwelling organisms, revealed the presence of oil in the digestive tract, other organs, and muscle tissue.

Data of Sanders, Grassle, and Hampson (1972) show immediate and nearly complete mortality of many forms of benthic animals following the spill of No. 2 fuel oil near West Falmouth, Massachusetts. The bivalve molluscs (clams, etc.) seemed especially vulnerable. After a few months, affected areas were recolonized by resistant forms. After about 10 to 20 months, the more sensitive molluscs resettled many areas.

Chemical analysis of edible shellfish species made following the West Falmouth spill revealed that the fuel oil had been absorbed or ingested and could subsequently be found in oyster bodies and scallop muscles in quantities sufficient to require the closure of shellfish beds to harvesting.

During drilling operations, drill cuttings are separated from the drilling fluid, cleaned of any entrained oil and discharged into the ocean. A diver survey during one operation revealed that the drill cuttings could be detected over a circle 100 feet in diameter. In a small area in the center, the deposit appeared to be about four feet thick. The same survey of the cuttings deposit showed that benthic animals either migrated up through the deposit as it accumulated or colonized even as deposition continued because it appeared to be inhabited by several animals characteristic of "normal" benthic fauna.

During entrenchment of new pipelines most, if not all, benthic fauna are either destroyed by the jetting or raised into the surrounding water and rendered completely vulnerable to predation. Although recolonization would begin immediately, the native fauna could not be fully restored until seasonal reproduction cycles had been completed by representative species from adjacent areas, which would provide a supply of larvae to settle and enter the reworked substrate.

Turbidity resulting from resuspended sediment could have an adverse impact on filter-feeding apparatus by blocking respiratory surfaces. Another possible source of impact is the resuspension of toxic heavy metals and persistent pesticides that may have been deposited in the area by a polluted stream or runoff. The possibility exists that these toxic materials could be ingested by lower marine life and could then be magnified through the food chain until they accumulated in serious quantities in top carnivores, including species harvested for human food.

Impact on beach and associated biota

Impacts on the beach and associated biota could result from contamination by spilled oil and from disruption in the depth of pipeline burial excavations.

A study on three sandy beaches oiled during the Santa Barbara spill revealed no conclusive results concerning the impact on marine fauna (Trask).

During the Arrow spill study excavation of clams revealed oil extending down most burrows. Some mortality of clams occurred and even the live clams were unresponsive.

Other pollution studies for the littoral zone are concerned with rocky shorelines and their characteristic assemblages of seaweeds, barnacles, limpets, anemones, etc., and consideration of physiological stresses leading to death in oiled plants and animals. To generalize, where organisms have been covered by crude oil and Bunker C fuel oil, death is primarily blamed on smothering due to the physical coating. When the pollutant has been a lighter refined oil (No. 2 fuel oil, diesel fuel), death and stress have been associated primarily with toxic effects of the oil.

It is also possible that shorebirds could receive an oiling. The results would be the same as for pelagic seabirds.

Burrowing animals and rooted plants in the path of pipeline laying operations will be killed or damaged. At least one growing season would be required for the impact to be abated.

Impacts on embayments, channels, water courses and associated biota

Living organisms in estuarine and inland waters could be adversely affected by spilled oil and by dredging activity during the burial of new pipelines.

Oil pollution in the semi-closed waters of a bay system could be more serious than in the sea or along the open coastline because the pollutant would be, relatively speaking, entrapped with tidal flushing being its only source of removal. Many species undergoing early development in estuarine waters are vulnerable to even small quantities of toxic compounds containing oil. The drawbacks of past studies have been noted by Blumer (1971), who stated: "Unfortunately, chemical analysis (of potentially contaminated edible species) has not been used to support. . .studies in the past and conclusions on the persistence of oil in the environment have been arrived at solely by visual inspection. . . Marine foods may be polluted by petroleum and may be hazardous to man but neither taste nor visual observation may disclose the presence of the toxic hydrocarbons."

Impact on wetlands

The wetlands includes the mudflats, sand flats, coastal marshes, and bay and barrier island fringing marshes. Dominant vegetation consists of

spartina-type grasses and algae. Insects, worms, and protozoa are the dominant fauna. Large populations of waterfowl and wading birds are found also.

Three types of adverse impacts are possible in the wetlands environment: pollution by spilled oil, disturbance during pipeline construction, loss of habitat due to lands being taken for installation of onshore pipeline terminals and gas treating facilities.

As yet, no information has been found concerning the effects of oil in the Gulf states wetlands. It is unlikely that a marsh spill would spread far because of the physical hindrance caused by rooted vegetation, natural stream levees, canal spoil banks, and roads.

The impact of pipeline burial in the marshes will be the physical destruction of vegetation and immobile fauna in the path of the pipeline laying operation. The impact on a narrow band of marsh in the path of the pipeline operation will probably be severe but of short duration. In addition, new pipelines will probably result in the construction of onshore pipeline terminals or gas treatment facilities. The resulting impact will be the removal of a small amount of marsh habitat (on the order of five acres or less per facility).

Impact on air quality

The quality of air over the leasing area could be degraded by exhaust emissions of stationary power units and service vessels and by accidental release of oil and gas from wild wells.

According to one authority (Ley 1935, pp. 1073-1149) the average composition of natural gas as delivered to pipelines in the United States is:

Methane	CH_4	72.3%
Ethane	C_2H_6	14.4%
Carbon dioxide	CO_2	0.5%
Nitrogen	N_2	12.8%

(Small amounts of sulfur and other materials could also be present in some localities.)

If the wild well were not burning, the above gases would be released into the air. If the gas well were on fire, combustion would be essentially complete and the emissions would consist almost entirely of carbon dioxide (CO_2) and water; the nitrogen would remain as N_2 and any sulfurous gases would be oxidized to SO_2. The resulting impact would not be great.

If a wild oil well were releasing crude oil onto the water, the resulting impact would be substantially greater. If the oil does not burn, some of it will evaporate. A reasonable estimate of the range of emissions, assuming complete combustion, that an oil well fire could produce per 1,000 bbl. burned, might be as follows[1]:

CO_2	:	340,000-347,000 lb.
SO_2	:	620- 34,000 lb.[2]
NO	:	660- 10,000 lb.

(As a point of reference, during the Chevron 1970 fire and spill, the maximum spillage rate was estimated to be 1,000 bbl. per day.)

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[1]Values used in calculation are based on world averages for crude oil of 310 lb/bbl.; percent content by weight is: carbon-82.2 to 87.1, sulfur-0.1 to 5.5, nitrogen-0.1 to 1.5 (Levorsen, 1958).

[2]SO_2 emission would be less for Gulf of Mexico crudes which range from 0.1 to 0.5 percent sulfur.

Combustion of oil would, in reality, be incomplete; however, and emissions would contain somewhat less of the above compounds but would include, in addition, such materials as volatilized petroleum, particulate carbon, carbon monoxide, nitrous oxide, and sulfur monoxide along with other altered or partially oxidized matter.

Impact on water quality

The natural condition of sea water may be altered and degraded in several ways during oil and gas operations.

Debris and bilge will be released into waters from the many seismic vessels, crew boats, tugs, and service and supply boats used throughout the operation.

During drilling operations drilling fluids are usually cleaned and reused but drill cuttings are discharged into the sea. Most drill cuttings consist of sand and shales and therefore cause no turbidity, but settle to the bottom in minutes. The chemicals used in drilling muds have a relatively low level of toxicity and if discharged, produce a plume of turbidity in the water near the surface. The visible plume is on the order of a few feet wide and a few yards long.

The production and discharge of formation waters (oil-field brines) is a potential source of pollution. Three properties of formation waters contribute to water quality degradation if released into the sea. First is the small amount of entrained liquid hydrocarbon. Second is its high concentration of dissolved mineral salts. Third is the absence of dissolved oxygen in formation waters.

Water quality could be further degraded as the result of accidental oil spills. Part of this spilled oil would be removed by clean-up operations

and some would evaporate, but the largest proportion would probably be dispersed into the water.

Another source of water quality degradation is the resuspension of sediment during pipeline construction and burial. The duration appears to be on the order of several hours at a given location.

Impact on commercial fisheries

The general consensus of Gulf fishermen is that underwater stubs present the greatest problem; the presence of offshore structures is a moderate inconvenience; and the debris problem is minimal.

Removal of sea floor from use by trawlers

All shrimp and industrial bottom fish are caught by dragging a large trawl across the sea floor. Every site occupied by a drilling or production platform and its attendant service boats and barges must be avoided by trawlers. If the structure is a jack-up drilling rig or permanent production platform, the area of sea floor removed would amount to two to five acres. In deeper waters (over 300 feet) a semi-submersible drilling rig with its anchoring system would occupy up to 325 acres (assuming a 1,500 foot anchoring radius). The duration of exploratory drilling ranges from under 45 days for a single well to around six months for multiple well explorations. Permanent production platforms may remain in place for 10 to over 20 years. The probability that permanent platforms will be erected on each tract, based on past exploration success rates, is about 35 percent. It is estimated that each full tract (5,760 or 5,000 acres) developed will average three structures.

Creation of obstructions on the seafloor
that cause damage to trawling nets

Obstructions that may interfere with trawling are underwater stubs, large pieces of debris, and unburied pipelines.

Although Coast Guard regulations require that stubs be marked by a buoy at the surface if located in 80 feet or less of water, these buoys are frequently found to be missing. If a trawler pulls his net across a stub, it will certainly be badly damaged or lost.

Large pieces of debris, such as equipment, piping, structural members, tools and the like, if accidentally lost off a platform, service boat or barge, may damage trawling nets of fisherman unlucky enough to snag them.

It has also been reported that unburied pipelines (beyond the 200-foot depth contour) pose a serious problem to the shrimp trawling operations in the Gulf of Mexico (Farrelly 1972). A significant amount of shrimp trawling does occur in water depths where pipelines remain unburied.

Contamination of fish by spilled oil

Fish which are either externally coated or internally contaminated with oil are unmarketable. It has been shown that fish that live in the vicinity of chronic spillage are likely to be internally contaminated. Oyster beds have been contaminated in the past from oil spilled in the marshes, bayous, and bays in the delta region of Louisiana, but no known contaminated catches have ever been taken in the open waters of the Gulf.

Conflict with ship traffic and navigation

Despite the existence of fairways in some areas, the possibility of a collision with drilling rigs, permanent platforms, and their attendant vessels remains. Impacts which would result include loss of human life,

a spill of oil, release of debris including parts of (or entire) drilling rigs, and the ship, if it sinks. The contents of the ship's cargo could pose a serious threat to the environment if it includes toxic materials such as chemicals, crude oil, or refinery products.

Floating trash accidentally lost off platforms also constitutes a hazard to boats.

Impact on recreation, sport fishing
and aesthetic values

Pipeline construction and burial disturbs a small area of beach (about 30 feet wide). The first high tides following burial of the pipeline will restore the beach terrain. The restoration of the beach ridge will take longer, most likely requiring a storm tide or high winds to obliterate the effects of the excavation.

An oil spill would directly affect water sports, such as swimming, diving, spearfishing, underwater photography, fishing for finfish and shellfish, boating and water skiing. Other activities such as beachcombing, shell collecting, painting, shoreline nature study, camping and sunbathing would be unattractive where an oil spill has coated a beach.

Sport fishing would be curtailed in the vicinity and for the duration of any spill incident. However, extensive testimony and evidence indicated that, overall, oil and gas operations have a favorable impact on sport fishing activities. Sports fish congregate near offshore platforms, which serve as artificial reefs. In the open sea, offshore platforms provide both food and cover in areas that are largely devoid of those essentials. Myriad forms of micro-organisms in the water drift by these structures and attach them selves, soon encrusting all exposed surfaces on the platform.

Adverse aesthetic impacts result from floating debris or oil washed into bays or onto beaches, temporary scars from pipeline burial, and visibility of some nearer offshore structures from the shore.

Impact on land use and
land use trends

Pipeline laying and the construction of pipeline terminal facilities temporarily disrupt a small amount of land. Since pipelines onshore are buried, there would be no permanent loss of the land for grazing, farming, etc.

Exploration and production in new offshore areas could require a marginal influx of labor and a redistribution of population due to the absence of a large petroleum-based industry and a labor force with the necessary skills.

Matrix analysis of adverse impacts

The matrix is a device for displaying interrelationships of some of the impact-producing factors (on the horizontal axis of each matrix) with coastal activities and resources which could sustain an impact (on the vertical axis of each matrix) and for assigning values for those interrelationships.

Significant resource factors which could sustain negative impacts as a result of development appear on the vertical axis of each matrix in two groups: Natural Resource Systems (refuges/wildlife management areas, estuary/nursery areas, marshland, and beaches) and Coastal Activities/Multiple Uses such as national park units, commercial and sport fishing areas, recreation (boating, swimming, water-oriented activities other than sport fishing), and shipping.

The factors which could produce impacts on these resources and uses include: debris, the platform itself, oil spills, pipeline construction,

storage facilities, support services, labor forces, production. An overall matrix, (Table 7) suggests the general nature of impacts resulting from OCS activities.

Accidents and oil spill events associated with OCS activities

In any complex industrial operation involving heavy equipment, flammable materials, work at sea, and large numbers of employees, it is inevitable that accidents will occur.

Natural gas leaks associated with blowouts

Information furnished by the Geological Survey for the period 1956-1971 lists 30 gas leaks associated with well blowouts during OCS oil and gas operations in the Gulf of Mexico. Ten of these incidents involved fires and four were associated with oil or condensate spills. The duration of the blowouts ranged from two hours to over seven months. Several incidents included the loss of life and equipment but none of the leaking gas resulted in identifiable environmental damage. There are no estimates available of the amount of gas lost.

Major oil spills

Data supplied by the Geological Survey for the period 1964-1971 indicates a total of 39 significant oil spill incidents involving 50 bbl. or more of oil and condensate connected with Federal OCS oil and gas operations in the Gulf of Mexico. The estimated total volume of oil spilled during this period as a result of these incidents is slightly less than 280,000 bbl.

Table 7

General Summary of Environmental Impacts Which Might Result from OCS Oil and Gas Operations

Impact Sustaining* Factors	Impact Producing Factors*							
	Debris	Plat-form	Oil Spill	Pipl Const	Storage Facil.	Support Serv.	Labor Force	Prod.
1. Refuges	(-)		(-)	#	#			
2. Estuaries	(-)		(-)	(-)				
3. Marshland	(-)		(-)	(-)	(-)	(-)		
4. Beaches	(-)	**	(-)	#	#			
5. National Park Units	(-)	**	(-)	#	#			
6. Com. Fish.	(-)	(-)	***	##				
7. Sport Fish.	(+)	(+)	***	##				
8. Recreation	(-)	**	(-)					
9. Shipping		(-)						
10. Regional Economy		(+)		(+)	(+)	(+)	(+)	(+)

*The principal type of relationship between impact producing and sustaining factors is indicated by (+) positive impact or (-) negative impact. In some relationships, both positive and negative relationships are possible; in these areas, the type of relationship considered dominant is shown.

**Impact will be negative only if platforms are visible, i.e., impact will be on aesthetic values.

***Impact of oil pollution on nearshore and estuarine shellfish is negative; impact on open-water finfish and shellfish is not well understood, but oil spills adversely affect sport and commercial fishing activity.

#Impacts would be excluded by administrative action, e.g., pipelines or storage facilities would not be permitted in refuges, National Park Units, or on those recreation beaches subject to official regulation.

##Impacts would occur during construction stage only.

In the past, large amounts of oil have been spilled when dragging anchors severed pipelines. The chance for this type of accident has decreased because many older pipelines have sunk into the sediments and new Bureau of Land Management regulations require burial of pipelines.

Most platform fires are probably caused by combustible hydrocarbon liquids or vapors coming into contact with electrical devices and overheated mechanical devices; more rarely they could be ignited by lightning or static electricity. Sometimes, platform fires first involve the accidental ignition of fuel, solvent, or heat exchange fluids. If caught soon enough, these small fires are usually controllable but, once a storage tank or well catches on fire, major structural damage occurs and the pipes of adjacent producing wells on the platform may be severed contributing to the fire.

If producing wells are damaged in a way that allows them to flow freely and be ignited, they are usually allowed to burn while operations are underway to control the wild well from a remote location. In this way, a high percentage of the hydrocarbon liquid expelled by the well is burned and little ocean pollution results. If a blowing well is releasing mostly or entirely natural gas, the possibility of ocean pollution is minimal.

Accidents caused by human error during routine rework, maintenance and repair have resulted in at least two large spills of oil, along with destruction of platforms, the loss of a work vessel and several human lives.

Summary

During the period of 1964-1971 almost two billion bbl. of oil and condensate were produced in the Gulf of Mexico offshore Texas and Louisiana. The amount of recorded spills during this period represents 0.014 percent of all oil and condensate produced in the area during the same period.

Year	Number of Incidents	Total Production/bbl.	Total Spilled/bbl.	Percent of Production Spilled
1964	5	122,500,126	14,928	0.0122
1965	1	144,968,615	500	0.0003
1966	0	188,714,070	0	0
1967	2	221,861,614	160,704	0.0720
1968	2	266,936,001	6,085	0.0023
1969	8	302,919,143	10,924	0.0036
1970	7	335,658,540	84,323	0.0251
1971	20	387,445,398	1,473	0.0004

The number of incidents shows an increase starting in 1969. This is the same year that Gulf of Mexico OCS operating orders became effective requiring the recording of all spills, reporting of all spills greater than 15 bbl., daily inspection of manned facilities and regular inspections of unmanned facilities. There has been a total of 10 oil spills of 1,000 bbl. or more in over 18 years of OCS leasing. Six out of the ten major oil spills occurred during the period 1964-1968 and four during the period following implementation of the OCS operating orders of 1969-1971.

Minor spills

During the first nine months of 1972, 839 minor spills of less than 50 bbl. involving 836 barrels (42 gals/barrel) of oil were recorded by the Geological Survey from OCS oil and gas operations in the Gulf of Mexico. The majority of these spills (682) involved one barrel of oil or less totalling 170 bbl. Only five spills exceeded 15 barrels of oil (141 barrels). An additional 499 oil slicks from unidentified sources were sighted in the first nine months of 1972 and are not positively related to offshore drilling. There is evidence of natural oil seepage in the Gulf of Mexico and possibly these natural seeps could be the source of some oil slicks classified as being from an "unidentified source."

Collisions resulting from conflict between ship navigation and offshore structures

During the period July 1, 1962, through June 30, 1971, the Coast Guard recorded 24 incidents of collisions between vessels and fixed platforms. Total damages were estimated to be about $0.4 million to vessels and $3.4 million to the structures. Only four injuries and no deaths were reported. During the time period 1957-1971 the Geological Survey recorded only one significant spill of oil, 2,560 bbl., associated with ship-platform collisions.

Accidental deaths and injuries on oil industry structures and vessels

Information supplied by the U.S. Coast Guard reveals that a total of 94 individuals were killed as a result of accidents involving construction, supply, drilling vessels, workboats, mobile drill rigs, and artificial islands in the Gulf of Mexico and adjacent navigable inland waters during the period 1964-1971. Of these 94 deaths, approximately 60 occurred in water approximately equal to the Federal OCS area. These figures do not include deaths resulting from accidents in which no vessel or rig damage occurred (persons falling or knocked overboard, crushed by drilling equipment, etc.). Partial figures for fiscal year 1967 through 1971 indicate that approximately 25 persons were killed in oil operations in the Gulf of Mexico (both inland and international waters) where no casualty to the vessel was involved.

Onshore Production

This alternative would require increased exploration, development, and production of crude oil (and natural gas) from onshore sources. To be a realistic alternative, supplies of oil and gas equal to all or an appreciable part of projected coal supplies from the Eastern Powder River Coal Basin of Wyoming would have to be developed in addition to those presently used. Experience indicates that it would be extremely difficult, if not impossible, to extend drilling efforts to provide additionally needed oil and gas supplies, especially when considering the drilling effort required to offset continuing declines in onshore production. Past discovery rates indicate that an indeterminate number of successful wells would be required to provide an energy supply equivalent to that which could be supplied by the Eastern Powder River Coal Basin of Wyoming. In 1970, less than 30,000 wells were drilled in onshore areas.

Onshore drilling in recent years has continually declined; a major contributor to the decline has been a lack of economic incentive. Additional incentives such as subsidies, price increases, and tax benefits could result in increased drilling and development of onshore domestic supplies, but little information is available to evaluate the cost effectiveness of such a program. With increased incentives, additional exploration, development, and production of supplies could be expected; however, increases in crude oil supplies from new discoveries could not be expected to be forthcoming in large enough quantities to offset the energy production from the Eastern Powder River Coal Basin of Wyoming.

Two hundred forty-six billion barrels of crude oil are estimated to be recoverable from domestic onshore areas, including the Alaskan North Slope, under current technological and economic conditions. Potential onshore

resources would be adequate to meet projected requirements but past and current drilling efforts have not resulted in discoveries that would have provided adequate increased production. The most favorable geologic provinces already have been developed, thus possibilities for successes are reduced. In the late 1940's, only 30 wildcat wells were needed to locate a large new field; the number of wells required had nearly doubled by 1960 and this trend continues.

The importance of finding large fields becomes apparent when it is noted that in 1972, 63 percent of U.S. production was from only 264 giant fields. There are over 35,000 oil fields in the United States.

Development of spare shutin capacity in the Naval Petroleum Reserve at Elk Hills in Kern County, California, could be a partial alternative. Production has been limited to about 2,000 barrels of oil per day. In 1970 shut-in capacity was estimated to be about 160,000 bbl/d. At that time, it was estimated that an expenditure of approximately $100 million for drilling and for plants and compressors, and $50 million for additional transportation facilities could result in increased production to about 350,000 barrels of crude oil per day (Oil and Gas Journal 1970). Congressional approval would be required for any appreciable increase over the current producing rate.

Technological advances permit improved recovery of oil from existing reservoirs, and, in effect, increase the recoverable reserves in a producing formation by secondary recovery. Further improvements may be expected. However, the existing forecasts usually and often explicitly include provision for some improvements in recovery. For example, the National Petroleum Council projects reserve additions of 28.5 billion barrels, or 71 percent of its 1971-1985 totals, from application of secondary and tertiary recovery processes (National Petroleum Council 1971, p. 136). Much production capacity added in

recent years has been obtained through such improvements, and further dramatic increases are generally not anticipated without increasing cost and price levels.

Ultimate recovery of oil is currently estimated at 31.1 percent of original oil in place. The applicability of recovery techniques depends strongly on the nature of the oil reservoir; the estimated recovery ranges from 13.5 percent in Ohio to 65 percent in District 6 of Texas. With estimated original oil-in-place of 425 billion barrels, and increase of only one percent in the average recovery or oil in place would yield 4.25 billion barrels, or 2 million barrels per day for 12 years. However, an assessment (U.S. Department of the Interior 1972a, p. 67) of recovery trends stated that:

> "The rate of improvement in recovery efficiency appears to be diminishing rapidly, however. The fact that an average of only one-third of the discovered oil in the ground is being recovered currently, and that significant oil deposits are becoming more difficult to find, emphasizes the need for a continuing research effort in these areas."

Technological processes

The development and final utilization of oil and gas involves a wide range of operations, wherein the oil and gas must be found in a natural underground reservoir, lifted to the surface, transported to refineries, refined into more than a thousand products, and, finally, marketed and distributed.

Exploration

The first phase in petroleum production involves locating the hydrocarbon reservoir. Generally petroleum is found in porous sedimentary rocks where favorable geologic conditions have occurred to form traps. The two favorable geologic conditions necessary to form a trap are a layer of porous,

permeable rock, usually sandstone or limestone, whose tiny pores may contain the hydrocarbons, and adjacent impervious layers of rock such that a barrier is formed to halt the movement of the hydrocarbons and, hence, enable their accumulation. Oil and gas, after they were formed, migrated through the pores in the rock until they reached an impermeable barrier. Here they accumulated and reached a steady state under relatively high pressure. Not all traps contain oil and/or gas, but those that do are called reservoirs. Three of the most common traps are the anticlinal, fault, and stratigraphic traps.

The anticlinal reservoir is formed when a layer of porous rock, bounded above and below by impermeable layers of rock, is uplifted in such a way that the hydrocarbons are held in the crest of the porous layer. Hydrocarbons, being less dense than water, assume the higher position, and gas, if present as a separate phase, may form a "cap" by assuming the highest position in the trap.

In the fault trap reservoir, the porous layer abuts on an impermeable rock mass, placed there by faulting. The impervious layer prevents further lateral or upward migration of fluids.

In the stratigraphic trap, the porous layer abuts on an impermeable rock mass that is not the result of faulting, but the product of other geologic processes. In whatever manner the layers arrived at their configurations, when a porous stratum is surrounded by impervious strata and its pore spaces contain hydrocarbons and/or water, a reservoir is formed and the fluids are held in place in the trap.

These traps are initially located by a seismic survey. In seismic exploration an energy source generates a series of small amplitude seismic pulses that travel at thousands of feet per second through the earth and are

reflected and refracted by the various subsurface strata. An array of sensitive geophones detects the returning seismic waves and records them on magnetic tape. These recordings are subject to highly sophisticated electronic data processing resulting in an end display of cross-sections and maps of the various subsurface formations and, hopefully, they will reveal and locate some of the above pictured traps. Formerly, seismic exploration revealed only these trap structures; they did not reveal the presence or absence of hydrocarbons, nor did they reveal traps not formed by the shape of rocks. Very recently, however, new techniques have been developed which more readily reveal traps and which provide some clues as to the presence or absence of hydrocarbons. Receiving devices that have greater sensitivity can record echoes from the substrata with such precision that the strengths of these echoes can be measured. Stated simply, water-filled strata return a weaker echo and an echo of opposite polarity than strata filled with hydrocarbons (Savit 1973; Lindsay and Craft 1973, p. 23). While these new techniques in seismic surveying may not be foolproof and may not indicate whether or not a hydrocarbon reservoir contains enough oil or gas to be commercial, they are an important improvement in exploration for hydrocarbons. The final step in the exploration phase is the drilling of a "wildcat" well which is the actual proof of whether or not the suspected structure actually exists, and, if so, whether or not it is a trap that contains oil and/or gas in commercial quantities.

Drilling

Most present day drilling is performed with a rotary drilling rig. The hole is dug by a drill bit which grinds the rock. The bit is located at the end of a string of drill pipe. At the surface, the drill string

including the bit is turned by a rotary table and a special square or hexagonal joint of pipe called a kelly joint. At the bottom of the hole, the action of the bit crushes the rock and advances the hole. To remove the cuttings, a circulating fluid called mud is pumped down into the hole through the kelly, drill pipe, and bit. The mud that comes out of the bit picks up the cuttings and transports them to the surface as the mud continues flowing upward in the annular space between the drill pipe and the wellbore.

The mud serves another purpose equally as important as removing the cuttings from the hole. That is, the column of mud exerts a hydrostatic pressure on the formations that have been or are being penetrated. Whenever a fluid-bearing formation is encountered by drilling, the weight of the mud prevents the formation fluid from entering the wellbore. This is essential for preventing an uncontrolled rush of gas or oil into the wellbore, possibly flowing uncontrolled to the surface and causing a blowout. Blowouts are extremely dangerous because they are difficult to control and the highly flammable nature of hydrocarbons poses a threat to all concerned. It might be noted, on the other hand, that since drilling mud keeps formation fluids out of the hole, it is possible to drill through a hydrocarbon-bearing formation without being able to detect it.

To confirm the existence or absence of hydrocarbons, various tests must be performed. The two most commonly used methods are logging and the drill-stem test. Logging consists of lowering an electrical device into the wellbore to measure various electrical properties and provide clues as to which formations contain hydrocarbons. The drill-stem test is a method by which the well is temporarily completed and is allowed to flow through the drill pipe.

From the resultant flow, the fluids obtained confirm the existence of oil or gas.

Well completion

Once the existence of a commercial reserve of oil or gas has been confirmed by logging or by a drill-stem test or other method, the well must be completed. To complete the well, the drill string and bit are removed and a string of large diameter pipe (called casing) is lowered into the hole far enough to reach or pass through the hydrocarbon zone. The empty space between the casing and the wellbore is filled with cement to seal off the various formations which have been drilled. Adjacent to the hydrocarbon-producing zone, the casing and cement are perforated so that oil or gas can drain into the well. The placing of the casing having been completed, tubing is placed in the well. The tubing is simply a smaller diameter string of pipe that fits inside the casing and conveys the fluids to the surface. Finally, a wellhead consisting of control valves is installed on the surface. Fluids travel up the tubing, through the wellhead and into a gathering line which takes the gas and/or oil to be further treated.

Hydrocarbon reservoirs may be sizeable and it is an important part of developing a field to drill a sufficient number of wells as to develop the resource in the most profitable manner without waste. Additional wells are drilled and completed in the same manner as described above.

Production

Crude oil is brought to the surface from the reservoir by artificial means or by natural flow if there is sufficient reservoir energy in the form

of pressure. The reservoir pressure and gas in solution determine the available driving forces. Artificial lift is accomplished by pumping or by injecting high pressure gas into the well to gas-lift the fluid. Gas produced from a gas well flows to the surface under its own pressure.

The fluid produced from gas wells is essentially only gas and may go directly from the wellheads via gathering lines to a gasoline plant or to a common carrier main pipeline.

The fluid produced from an oil well is comprised of both oil and gas and usually water so provisions must be made for separating the three components of the fluid before quantitative measurements can be taken. Normally the fluid flows from the well to an oil and gas separator. The gas is metered and sent to a pipeline, the water and oil are sent to another type of separator, and the oil then proceeds to a stock tank while the water is disposed. The crude usually is gauged in the stock tank; oil production in the U.S. is measured in stock tank barrels. From the stock tank, oil is then transported via pipeline to a refinery tank farm.

Refining and marketing

Finally, the crude oil enters the refinery where it is converted into the thousands of specialized products which modern refining techniques are capable of producing. The majority of the natural gas goes directly to both domestic and commercial fuel consumers via pipeline. The specialty products from the refinery are usually packaged at the site (drums, cans, bottles, cases) and moved to the final sales point by air, rail, or highway. Large volume products (gasoline, jet fuel, and fuel oil) are delivered by pipeline to area tank farms and then to retail outlets or final consumers via tank truck.

New technology in exploration, production,
transportation, refining

The evolution of new technology has resulted in improved search techniques. Perhaps the most promising new development in exploration is the more sensitive receiving device that enables the surveyor to determine not only the presence of a trap structure, but also whether or not the structure contains hydrocarbons. This seismic breakthrough has been used in the OCS area from Florida to Texas in the Gulf of Mexico and has revealed many promising areas that may contain large amounts of oil and gas.

Improved technology in production methods has been particularly noteworthy. Water flooding has been developed into a process whereby an amount of oil can be recovered that is approximately equal to the volume of oil recovered by primary methods.

Fracturing is a method whereby the producing capability of a particular well can be increased. In hydraulic fracturing water under pressure is pumped into a well. The water enters the formation and actually enlarges the cracks in the reservoir rock. A propping agent such as little glass beads or sand is mixed in with the fracturing fluid and is also pumped into the well. The propping agent is forced into the newly opened fractures along with the fluid and remains in place after the well is drained. As the name implies, propping agents keep open the fractures after the fracturing fluid is removed. With a widening of the fractures, the oil can flow with greater facility toward the well and into the wellbore. Another similar method of opening fractures in reservoir rock is by acidizing. This involves pumping acid into the well to dissolve some of the rock and enlarge the fractures so the oil can flow more freely.

Concerning transportation of hydrocarbons, recent technological developments have resulted in decreasing cost levels. Of particular significance has been the installation of highly automated, large diameter, thin walled (high strength steel) pipeline systems as well as better protective coatings and insulation.

Technological advances in the refining phase of petroleum production have mainly come about through an increase in the use of computers. Complementing the increasing trend toward automation, recent advances in the technology of petroleum refining have resulted in increased production, reduced operation costs, and improved quality control.

Resource base

Oil and gas reserves are located in many areas of the United States but the largest reserves are found in the mid-continent and Gulf Coast regions.

Table 8 shows the U.S. Geological Survey's latest calculations of proved onshore oil and gas reserves. The table also presents the Survey's estimate of recoverable resources. Offshore reserves are not included in these figures.

Table 8

U.S. Onshore Oil and Gas Reserves and Resources
Oil in Billions of Barrels; Gas in Trillions of cubic feet*

	Proved Reserves		Recoverable Resources**	
	Oil	Gas	Oil	Gas
Public lands	3.0	14.0	250.0	1,153.0
Non-public lands	38.3	237.6	16.0	61.0
Total	41.3	251.6	266.0	1,214.0

*Includes natural gas liquids.
**Does not include proved reserves.

Alaskan oil and gas reserves

The Prudhoe Bay field currently is estimated to contain 24 billion barrels of oil-in-place. At an estimated recovery rate of 40%, the current proved recoverable reserves of the field are 9.6 billion barrels of crude oil (American Gas Assocation 1971, p. 27). These reserves alone make the Prudhoe Bay field the largest ever discovered on the North American continent. Nevertheless, the 9.6 billion barrel estimate may be a conservative indication of the crude oil potential of the field and the Arctic Slope province.

The current reserve estimate for the Prudhoe Bay field is for unextended pools and assumes primary recovery only. With further developmental drilling and application of secondary recovery techniques, it is likely that at least 20 billion barrels of crude oil will eventually be recovered from the Prudhoe Bay field. This would make it the fifth largest oil field ever discovered in the world (Halbouty et al. 1970).

The Prudhoe Bay field has large reserves of natural gas dissolved in or associated with its crude oil reserves. Recoverable gas reserves in the field were estimated to be 26 trillion cubic feet as of the end of 1970 (American Gas Association 1971, p. 170). An average of 750 cubic feet of dissolved gas per barrel for the proved oil reserves of 9.6 billion barrels would indicate reserves of approximately 7 trillion cubic feet of dissolved gas and 19 trillion cubic feet of associated gas. These reserves, which, like the crude oil reserves of the Prudhoe Bay field, are subject to extension and revision, constituted 8.9 percent of recoverable U.S. natural gas reserves at the end of 1970 (American Gas Association 1971, p. 124). They also make the Prudhoe Bay field the thirteenth largest gas field ever discovered in the world.

The estimated reserves of the Prudhoe Bay field do not exhaust the oil and gas potential of the Arctic Slope province in Alaska. The Prudhoe Bay field is located in the Colville Basin. Geologically, this basin is classified as an intermediate crustal type (i.e., its underlying crust is intermediate to that beneath continents and that beneath oceans), the basin itself being extracontinental (located on the margin of a continent) and sloping downward into a small ocean basin. Extracontinental, downward warping basins are among the richest sources of oil and gas in the world. Examples of such basins include the Arabian platform and Iranian basin (Persian Gulf), the East Texas basin, the Tampico embayment (Mexico). Over half of the 119 known oil fields with at least one billion barrels of recoverable reserves are found in the 10 known basins of this type.

The ultimate potential of the onshore area in the Arctic Slope province is uncertain. The platform along the Arctic Coast gives considerable geologic indications of being very favorable for both oil and gas (Gryc 1971; Brosge and Tailleur 1971). Comparison with the history of similar basins indicates a high probability of further discoveries of varying size. Professional estimates of ultimate recovery for the province range from 30 to 50 billion barrels (Cram 1971; Schurr and Homan 1971, pp. 86-87). The Prudhoe Bay field alone is likely to supply 20 billion barrels of crude oil. Considerably higher estimates than these have been made but the geologic evidence for them is lacking. (Governor Egan of Alaska was quoted in The Oil Daily July 7, 1971, p. 3, with an estimate of 150 to 300 billion barrels.)

Similarly, the natural gas prospects of the North Slope are not limited to the Prudhoe Bay field. Several gas fields were discovered in the 1940's and 1950's on NPR-4 (Naval Petroleum Reserve No. 4), and the largest of

which was the Gubik field with 300 billion cubic feet of reserves. Geologic investigations of other parts of the North Slope have indicated a favorable potential for future gas discoveries within them as well.

Economic considerations

Prices and costs

An overview of the major factors affecting oil and gas cost-price relationships is amply provided in the National Petroleum Council report entitled "Factors Affecting U.S. Exploration, Development, and Production, 1946-1965." Highlights of that presentation include the following: (1) federal and state policies with respect to leasing of federal and state lands, taxes and production, and unitization of properties; (2) the changing behavior of price relative to cost factors such as wage rates and payments for oil field materials and machinery; (3) the decrease in many areas of geological opportunities to make profitable discoveries, especially the older shallow areas, and the shift to the more expensive operating areas of Alaska and deep inland areas; (4) the changing structure of the industry which is evident in the decline of small companies and individuals and increasing concentration of operations among the large integrated companies; and (5) a decreasing proportion of total industry's revenue from oil and gas production spent on domestic exploration and drilling.

Economic factors governing the level of crude oil prices at the wellhead are established for areas and fields on the basis of oil and/or gas quality and type, market supply-demand relationships, the competitive relationship of oil as delivered to refineries compared with oil from other fields, and other factors. The 1972 average wellhead value of crude oil in the U.S.

was \$3.39 per barrel with the value of natural gas averaging 18.6¢ per thousand cubic feet. The gross value of revenues from production of petroleum totaled over \$11 billion; the gross value of gas totaled about \$4 billion.

Because of the general industry attitude concerning the confidentiality of cost data coupled with the physical properties of oil and gas, the environment in which they are found, and the manner in which they are produced, projections of the cost for finding and producing oil and gas are subject to considerable uncertainty. Further complicating the determination of oil and gas costs is the association of oil and gas in the same reservoir and the consequent producing operations to handle both oil and gas simultaneously. In 1972, it was estimated that the cost incurred in drilling and equipping wells and other yearly costs of finding, developing, and producing oil and gas in the U.S. was about \$4.8 billion. Of this, about \$2.25 billion was for lease bonuses, \$1.9 billion for drilling and the remainder for production and equipping wells (Oil and Gas Journal 1973, pp. 13, 14). In 1972, 29,510 wells were drilled which found 1.5 billion barrels of oil and 9.6 trillion cubic feet of gas (American Gas Association 1973, pp. 24-120). The American Petroleum Institute/American Gas Association have released their latest figures covering the year 1971 and have shown the cost of finding oil and gas in 1971 to be \$1.98 per equivalent barrel (World Oil 1973, p.75).

Industry structure

In the United States all phases of the development and utilization of petroleum and natural gas are performed by private companies, both large and small. The primary operations performed by these corporations include 1) the search for and production of petroleum, 2) the transportation

of petroleum from producing fields to refineries and distributors, 3) the refining of crude oil, and 4) the distribution of petroleum products to consumers.

Firms in the petroleum industry exhibit varying degrees of vertical integration as they perform one to all of the mentioned phases. Often subsidiary companies are formed to undertake supporting functions.

Major companies operate throughout the United States but predominate in areas requiring large investments for drilling and producing operations. Such areas include west Texas and Alaska. Petroleum located in mature producing areas is frequently produced by small independents and individuals. Recently many major and large independents have expanded their operations into other energy resource fields as well as petrochemical manufactures and other business areas.

The petrochemical industry is the nation's third largest industry, following agriculture and public utilities. The natural gas industry is the nation's sixth largest industry. Because natural gas occurs in association with petroleum, these commodities are often produced jointly.

Petroleum refineries are situated near producing areas, water transportation facilities, or large market areas. As of 1969, 20 companies controlled 80 percent of the 264 refineries in the U.S. In the natural gas industry 90 percent of interstate sales were made by 10 percent of the producers.

Pipelines and water carriers, including tankers and barges, are the primary modes of transport for three-fourths of the movement of crude oil and all but a negligible fraction of the distribution of natural gas.

So important are pipelines to the natural gas industry that recent increases in the production of natural gas can be attributed largely to major extensions of trunk pipelines. Successes in pipeline technology, including the development of high-quality pipeline steel, welding processes, trenching machines, and efficient compressors, have played a significant role in spurring the growth of pipeline systems. Surface tank trucks are used to transport crude oil over short distances, with railroad tank cars reserved for the transport of higher value specialty products. Trucks in recent years have occupied a larger percentage of the transportation mix for refined products.

The domestic cost of transporting crude oil to the refinery may amount to as much as 50 to 60 percent of the delivered cost of oil. Cost for various types of petroleum transportation, including both short and long hauls, are compared as follows:

Type of Transportation	Mills Per Ton-mile
Tanker	1.0-2.0
Barge	1.5-6.0
Pipeline	1.7-6.0
Tank Car	20-70
Tank Truck	30-50

From the above tabulation, it is evident that transportation costs bear an inverse relationship to the size of the mode of transport. Conversely, lower costs reflect longer hauls and the use of large-capacity carriers. Economies in the transportation of petroleum products have been achieved through increases in the scale of operations, greater use of automation, and better design and quality of materials.

Transportation of Alaskan oil. Under the Trans-Alaska Pipeline proposal, all of the North Slope oil to be transported by that line would be delivered to and consumed on the West Coast (PAD V) within the first few years after full operation. Deliveries of oil from other fields and by other transportation facilities are too remote and too conjectural for meaningful consideration in current planning.

Given the large size of the Arctic gas reserves and the projected shortages in other sources of domestic energy, there is high probability that this gas will be developed. Three different consortia have made proposals for gas pipelines up the Mackenzie River Valley to the potential markets. However, many major uncertainties remain; for example, at this time industry experts differ in their opinions about how soon the gas caps in the Prudhoe Bay field can be tapped. Assuming 750 cubic feet of dissolved gas per barrel of oil would produced, 1.5 billion cubic feet of gas per day would be produced when oil production has met the full planned pipeline capacity and has come from the gas caps. The issue may not be fully resolved until several years after oil production begins, at which time empirical data on the effects of production of associated gas on the production of oil will be available. It is likely that a gas pipeline to the Midwest and lower Canada will ultimately transport gas from both the North Slope and the Mackenzie Delta region.

Environmental impact of increased drilling, production and transportation

Impact on air quality

The impact of additional petroleum drilling and production on air quality stems principally from the emission of particulates into the atmosphere as described in the following discussion; however, some disturbances result from noise and vibrations. As long as operations continue, the above-mentioned impacts will continue to occur.

Particulates are introduced into the air during construction and use of access roads and drilling pads. Often times, public use of the access ways for off-road vehicle recreation greatly aggravates the initial surface disturbance. Air quality in immediate areas of development will undergo deterioration because of removal of ground cover, vehicle traffic and occasional equipment failure or blowouts. The removal of vegetation cover raises maximum surface temperatures and permits increased local wind velocities and evaporation rates. The burning of waste petroleum and chemical products, especially those containing sulfur, could result in an increase of particulates, gaseous pollutants, and objectionable odors. Vapor venting from storage tanks should also be considered as an air pollutant.

Noise and vibrations from stationary engines used in drilling operations, pumping units and compressor stations can cause disturbances in natural environment and these disturbances will continue to occur throughout the life of petroleum-based operations. Noise and vibration could possibly alter the feeding and nesting habits of birds and animals, but it is highly unlikely that reduction in air quality from increased petroleum production could significantly alter conditions affecting the growth of plants and animals.

Impact on land quality

The modification of land form necessary for petroleum production results in varying degrees of environmental impacts on the physical and chemical land characteristics, the biological conditions, the cultural factors and the ecological relationships.

Depending on the terrain and local ground conditions, access to the drill site is normally from existing road networks, extension of these roads and expansion of trails. For initial exploratory work in a given area, only minimum alterations are made in roadway systems, but, after the decision is made to continue with development drilling, an improved road system is required for the transportation of the heavy drilling and production equipment.

The drill site must be cleared of vegetation and obstacles, graded and leveled. If metal storage tanks are unavailable, then reserve and waste pits must be dug to contain drilling muds and capture formation fluids to prevent pollution of the adjacent land and/or water. When production has been established, newly constructed roads are improved. The impacts resulting from these operations include removal of top soil and surface vegetation to establish corridors and alteration of drainage patterns and watershed cover.

In the construction of roadways, surface vegetation is removed and drainage patterns are modified. As a result, erosion can occur resulting in changes in landform. Trees, shrubs, grass, and crops may also be subjected to indirect effects by modifications of drainage patterns. Soil erosion and siltation can have both direct and indirect impact upon the normal behavior and activity patterns of wildlife. Small animals and birds may not

be significantly affected, although their number in the immediate vicinity of the operations might decrease in proportion to disturbances and lost habitats. Disturbance of the habitat may well continue beyond the life of the producing and transporting operations.

Land use and recreation activities may also be disrupted during drilling, producing and transportation operations. Aesthetic and human interest factors are affected for time-frames beyond the terminations of operations. Scenic views and vistas, wilderness qualities, and physical features in some localities could undergo alterations that could be considered permanent transformations. Population density, employment, and cultural life-styles would change from drilling, production, and transportation levels. The change would be of long-term impact and directly affect access, utility networks, waste disposal and creation of additional corridors.

While the construction of pipeline facilities has the potential for causing unfavorable environmental effects, the employment of good construction techniques can minimize or even eliminate most of these effects. Farming or grazing lands can usually be restored to their original condition after no more than one growing season by the replacement of top soil and the replanting of grass or crops. The aesthetics of wilderness areas can be preserved by using existing rights-of-way or minimizing the width of new rights-of-way by replacing grass and shrubs on the rights-of-way and by using such techniques as feathering and screening or deflecting of entranceways. Any displacement of wild animals will occur primarily during the construction. Banks can and should be stabilized to avoid erosion during construction. Access and service roads should be maintained with proper cover, water bars and

appropriate slope to avoid soil erosion. Compressor stations and other above-ground facilities can be located in unobtrusive sites and planted with appropriate trees and shrubs to enhance their appearance; location, planting and exhaust design can be used to abate excessive noise associated with operation of the compressor stations. Treatment plants can be located and equipped with devices to minimize any adverse effects upon air quality and suitable means, e.g., evaporation ponds or disposal wells, can be found for preserving the water quality of the surrounding area.

Perhaps the greatest adverse environmental impact from oil and gas operations results from oil, chemicals, brine, or waste material pollution. This pollution can result from spills, leaks, blowouts, human errors, or equipment failure. Although care is exercised to prevent land pollution, there are no fail-safe methods to completely protect the environment.

Land pollution, primarily from salt water and accidental oil spills, can result in soil sterilization that could be of a long-term nature and affect not only the topsoil but underground water quality. Native vegetation and crops can be adversely affected for short or long-term duratior depending upon the volume and toxicity of the pollutant, resistance of the flora, and the techniques and technology employed. Alterations of the flora in turn affect the habitat of birds and animals. Depending upon the degree of pollution, land uses such as agriculture, grazing, forestry, and wildernes can be altered for varying time-frames. In some cases large pollutant concentrations could be sufficient to kill vegetation, trees or crops and disrupt wilderness areas for long-terms. Recreation in areas subjected to large pollutant concentrations can also be altered for long time-frames.

Depending upon local conditions, aesthetics such as scenic views and vistas, wilderness qualities, unique ecosystems, or historical sites and objects may be altered. The degree of alterations would be dependent upon the degree of pollutant introduction and local conditions. Disruption of ecological relationships such as food chains and salinization of soil and water resources could result from pollutant contamination. The degree of contamination has a bearing upon the duration of the environmental impact.

In exploring and pipelining, any spills that occur normally would be small. Major spills could occur in drilling and production and in the movement of petroleum liquids by marine transportation. The Federal Water Quality Administration (EPA) estimates that 10,000 oil spills occur a year of which 2,500 are ground spills (National Petroleum Council 1972a, p. 146). Most ground spills cause little ground pollution. According to the 1970 report of the Office of Pipeline Safety (Department of Transportation) on spill incidents, spills averaged approximately 1,780 barrels of crude oil. Principal cause of over 50 percent of accidents was corrosion. Many onshore pipelines are old, dating back to 1920's before techniques for protection against corrosion became widely used. Continued accidents can be expected from these lines. With the development and expanded use of cathodic protection of pipelines, fewer accidents in new lines are expected, but accidents from old lines will continue to be of concern.

Impact on water quality

The construction of roads for access into prospective petroleum producing areas could affect water quality by disturbing drainage patterns and causing erosion. The dredging of canals could result in increased turbidity and resuspension of bottom sediments as well as salt water intrusion.

Turbidity is considered to be of short-term duration but may affect local flora and fauna. Siltation of water reservoirs and estuaries has long-range environmental impacts in that the shape and size of the water basin is altered. This can have an adverse impact on flora, recreation activities, and aesthetic qualities and, perhaps, disturb ecological food chain relationships.

One of the major environmental risks of petroleum production operations is the entry of foreign substances such as oil, chemicals, brine, and waste materials into the water cycle. Spills or leaks releasing these substances result from human error, corrosion of pipelines and vessels, ruptures or mechanical failures, burning pits, open ditches and blowouts.

Large amounts of salt water may accompany oil production as oil fields age. Such water can create pollution problems from producing wells on land or freshwater-covered areas. According to a study of the Interstate Oil Compact Commission (IOCC), up to 25 million barrels of salt water are produced daily from the nation's oil wells. Proper disposal of produced brines has been and continues to be of major concern to producing operators and regulatory agencies. Subsurface disposal is strictly regulated by some state conservation agencies and disposal of salt water is not permitted in freshwater streams.

The introduction of oil or brine into the water cycle can adversely affect vegetation and aquatic plants, birds, land animals, and fish. Sheltered lagoons and estuaries impose natural dispersal restrictions on oil spills causing the oil to remain trapped or concentrated in such areas for long periods. Major reductions in water quality that significantly disrupt the food chains in bays, lagoons, and estuaries could have long-term environmental effects.

Special considerations

Nuclear stimulation

Nuclear stimulation, an experimental method of fracturing low permeability gas reservoirs otherwise incapable of sustaining commercial production, has potential to add materially to U.S. recoverable gas reserves. The Atomic Energy Commission is conducting research and development of nuclear explosives and techniques for utilizing the effects of multiple nuclear explosives to recover natural gas locked in tight geological formations. Such gas cannot now be economically produced by conventional methods. Most reserves which are amenable to nuclear stimulation lie in thick, deep reservoirs of very low natural permeability located in the Rocky Mountain area.

Project Gasbuggy, a cooperative effort of the AEC, the Department of Interior and El Paso Natural Gas Company, involved detonation of a 29 kiloton nuclear explosive in the Pictured Cliffs formation, a gas-bearing formation near Farmington, New Mexico. The explosive, set off at a depth of approximately 4,200 feet on December 10, 1967, created an underground chimney containing about 2.3 million cubic feet of crushed rock. There was no unplanned release of radioactivity to the environment. By November 1969, nearly 300 million cubic feet of gas was extracted from the chimney through intermittent production testing of the well. A similar program, Project Rulison took place near Grand Junction, Colorado, in December 1969. It involved detonation of a 40 kiloton explosive at 8,430 feet.

Projects Gasbuggy and Rulison were basic experiments each involving the detonation of a single nuclear explosive but in different gas formations and at different depths. Both of these projects clearly demonstrated that

recovery of natural gas by nuclear explosive stimulation is technically feasible and economically promising. The current development phase involves techniques for using multiple explosives in a single wellbore. Gas formations amenable to nuclear explosion stimulation are thicker than can be effectively and feasibly stimulated by a single explosion. The Rio Blanco Project, part of this phase, involved simultaneous detonation of three 30-kiloton nuclear devices more than a mile underground on May 17, 1973. The stimulated well near Meeker, Colorado, is expected to produce 17.5 billion cubic feet of natural gas from sandstone formations. The gas should fill the chimney created by the explosions from where it can be piped to the surface.

The Atomic Energy Commission has reported on the possible scope of nuclear stimulation and has provided an economic assessment of the technical programs needed to achieve commercially viable application of nuclear stimulation of natural gas wells. Current emphasis in AEC's Plowshare program is to develop technology. A research and development period of approximately 5 years is required; it includes the design and testing of explosives and execution and evaluation of pilot tests in each basin. The Rio Blanco Gas Stimulation Project impact statement discusses a three-phase demonstration program for the Rio Blanco Unit which is being considered by the industrial sponsor but for which there is, as yet, no Government commitment. Assuming success during experimental testing, commercial development could begin by the late 1970's. A scenario developed by the Lawrence Radiation Laboratory (LRL) (Rubin, Schwartz, and Montan 1972) assumes technical capability and public acceptance of drilling, necessary field construction, and explosive firing of 80 wells (290 explosives) per year by 1980. This could result in the production of about 600 Bcf of natural gas per year by

that time. Favorable conditions might allow a development program of 100 wells (370 explosives) per year beginning in 1981. Such a schedule could yield 1.50 Tcf per year (4.35 billion cf/day) by 1985. This corresponds to an energy production of 4.35 trillion Btus/day.

Environmental impact

Environmental effects of nuclear stimulation to increase natural gas production from tight reservoirs are related to radioactivity and seismic disturbance, both of which concern the surface or subsurface, leaving atmospheric contamination or disturbance unlikely. The depth of the gas formations of interest throughout the Rocky Mountain area is such that the probability of releasing any appreciable amounts of radiation to the atmosphere at detonation time is considered negligible. Most radioactivity produced by the explosives will remain underground, trapped in the resolidified rock near the bottom of the chimney or attached to the rock surfaces in the chimney. Project design would take into account mobile waters and assure that chimneys remain isolated from them. The formations of interest for nuclear-explosive stimulations are generally at depths of 5,000 to 10,000 feet or deeper, have low permeability, and would not be expected to contain mobile water. Significant vertical communication with shallow water-bearing formations through existing or created faults or fractures must be avoided. Water produced with the gas from nuclear-explosive stimulated wells will contain very low levels of tritium. Control methods of disposal of this contaminant are being developed.

The chemical composition of the gas itself in each stimulated well is assumed to be similar to that measured in the first experiments. The initially large carbon dioxide concentration in the chimney either would be reduced by dilution with pipeline gas or would be removed by standard gas field practices. After production of a few chimney volumes, the carbon dioxide would be depleted and the gas composition would be essentially the same as that from conventional wells. Gas production from the wells could be delayed until short-lived radionuclides decay. Technical information from subsequent experiments will aid in defining the time for initiation of production.

The remaining gaseous isotopes--tritium and krypton-85--are produced with the first few chimney volumes of gas calculated to provide less than on milliroentgen per year of exposure to the general population if the gas were used as a part of the total gas supply to a large city. No insurmountable problem is anticipated in meeting future regulations or standards developed for sale of the gas.

The potential environmental impacts resulting from nuclear stimulation of a single well or in a small geographic area have been evaluated in the environmental statements prepared for the Rio Blanco (Atomic Energy Commission 1972) and the proposed Wagon Wheel (Atomic Energy Commission 1972a) projects. Extrapolation of the impact to a full commercial development relates primarily to the frequency and size of explosives and to changes in local environment as the areas of development expand.

The scenario developed by the AEC's Lawrence Radiation Laboratory describes drilling and firing of 100 wells per year (for possibly 50 to 60 years). On the average this would involve approximately 370 explosive

devices per year, usually 3 or 4 explosives in each well. The AEC estimates that four detonation days per year should suffice for the 30 to 40 wells to be completed for each field area. The size of the explosive required to stimulate the very thick geologic formations and the actual seismic effect of such devices are still being evaluated.

In extrapolating the projected or observed impact of test projects, consideration must be given to the total environment of the basin. The site for the Bio Blanco experiment, for example, is relatively isolated. There are thought to be no surface or subsurface structures or operations in the zone of substantial damage. The fact that this will not invariably be true is an important consideration when planning commercial development.

By its nature, nuclear stimulation has a dramatically disruptive effect on the nearby natural-gas host rock. The fracture zone should extend 300 to 400 feet from the center of the explosion. Also the compression wave moving out from the explosion can cause spall near a free surface (ground level) or other faulting or fracturing in areas where there is a large natural directional stress concentration. This would lead to concern if other valuable mineral resources exist in the area. However, the areas being considered for nuclear stimulation are relatively seismically inactive and would not appear to have large natural stresses required for such structural failures.

The development of nuclear stimulation of natural gas reservoirs may be accompanied by some possible damage of existing structures due to ground motion. Damages would have to be prevented (as by bracing) or repaired or compensation rendered to owners. Ground motion is predictable and utmost care would be used to minimize this effect.

It has been suggested that residual stress from a number of detonations might accumulate and present an earthquake stimulation hazard not present in a single detonation. The best evidence available on this point is from experience with the Nevada Test Site where data from seismic wave generation and from stimulated fault motion indicate that the cumulative effect of many explosions is to reduce ambient stress levels rather than to increase them. A recent series of high-precision geodolite measurements indicates, also, that the residual strain field around a single explosion site tends to relax with time. In any case, observations of the seismic effects of a series of detonations would permit continuing appraisal of this issue.

Deregulation of the wellhead price of natural gas

This alternative postulates increases in prices for natural gas to provide additional incentives to natural gas producers to increase natural gas exploration and development. Some additional crude oil would probably be discovered as a result of increased exploration for gas. Also, some crude oil demand would be displaced by incremental natural gas supplies.

Background.

The sale of natural gas for resale in interstate commerce is currently under Federal Power Commission (FPC) jurisdiction. In 1954, the Supreme Court ruled that independent producers of natural gas who sell for interstate commerce were not exempt from regulations under the Natural Gas Act.

In the past few years, the FPC has modified its pricing policies to be more responsive to the gas supply situation, and the FPC Chaiman, on

April 10, 1973, urged Congressional action to amend the Natural Gas Act to decontrol the price of new gas supplies. The President, in his energy message to Congress April 18, 1973, proposed decontrol.

Concurrent with the President's Energy Message, the Department of the Interior submitted to Congress proposed legislation to amend the Natural Gas Act. Until such legislation is passed by Congress, however, the wellhead price of new gas will continue to be regulated by the Federal Power Commission.

Resource base.

The Potential Gas Committee has estimated the remaining undiscovered resources of gas in the United States as of December 31, 1970, and has divided these resources by region and by degree of uncertainty. This amount is approximately 4.5 times the 1970 proven reserves of the conterminous forty-eight states, indicating that substantial additional reserves may be developed if economic incentives improve.

Economic considerations.

Deregulation of the price of new gas is a policy option that, if implemented, should stimulate the economic incentive for the discovery of new supplies and reduce inefficient use of the fuel. To determine the effectiveness of such policy options on these objectives, estimates of the extent of producers' and consumers' responses to increasing prices are needed.

When prices rise, producers have a greater opportunity for profit in developing resources which otherwise might seem too risky or uneconomical to develop. On the other hand, consumers are less willing to pay higher prices and may curtail some of their uses of the fuel, tending to bring supply and demand into balance. While supply and demand elasticities have been the subject of much research, very little is known of the quantitative relationships.

Demand elasticity.

Six economic studies on price demand elasticity were reviewed by Professor Draper in "Regulation of the Natural Gas Producing Industry" (Bram 1972, pp. 49-55).

Vermetten and Plantinga (1953). This study deals principally with the cross elasticity of gas and other energy sources in eleven industries aggregated by states. The elasticities ranged from -0.33 to -4.99 based on evaluation of 1947 data. (A -0.3 demand elasticity means that a 10 percent increase in price would cause a 3 percent reduction in quantity demanded.)

Wein (1961). This study used multiple regression analysis to solve twelve equations that relate factors thought to determine level of exploration with residential, commercial, and industrial demand. Cross-section analysis was used for the year 1961 for data aggregated by state. The results indicated that elasticity of industrial consumption was almost four times as large as the elasticity of residential and commercial consumption with respect to price; expressed differently, industrial users of gas respond more rapidly to higher gas prices by demanding less gas than residential and commercial users or by converting to another fuel. Industrial demand was highly elastic,

-2.5, whereas combined residential and commercial demand had an elasticity of -0.8. Professor Draper intimates that one of the more important uncertainties in the study is the choice of independent variables used to determine demand and exploration.

Villanueva (1964). This study attempts to establish the variables affecting gas demand of the major sectors of the consumer markets and to estimate the effects of different gas rates on the distribution of the fuel between consumer groups. Multiple regression analyses were performed with independent variables including prices on natural gas and competitive fuels, income, temperature, housing starts, and measures of consuming-industry activity for the period 1950-60. Price elasticities were calculated to be -1.83, -1.39 and -0.51 for regional gas demand of residential-commercial consumers in three of the five regions analyzed. Price elasticities of regional demand by industrial consumers ranged from -1.34 to -1.64 for three of the five regions. One major criticism of this study is that data were aggregated to such an extent that the number of observations of the variables was insufficient, which made difficult an interpretation of the statistically significant variables.

Balestra (1967). This study attempted to develop a dynamic equation for natural gas in the residential and commercial sectors of the economy. A short-run demand function relating demand to availability of gas, the stock of gas-using appliances, the real price of gas, and the real per capita income using 1950-62 data resulted in elasticities ranging from -0.00002 to -7.75. The conclusions were that the total demand for fuels is fairly inelastic in the short run; substitution of fuels must be small in

the short run given the consumers' stock of major appliances, and the upward trend in elasticity suggests that competition from alternative sources of energy may become stronger in future years. Draper (1972) summarized the limitations of this study as ". . . difficult to interpret the results when so many analyses were performed, their results are not in agreement, and there is no clear theoretical basis for choosing among the different models."

Tummala (1968). Two models were developed in this study to explain the demand for natural gas in the residential, commercial, and industrial sectors using annual times-series data for the State of Michigan from 1946-1964. For one model, the simultaneous equations model, burner tip price elasticities of demand in the residential, commercial, and industrial sectors were -0.44, -0.60 and -1.33, respectively. The other model, a distributed-lag model, produced some results not in accord with economic theory. Major problems were with the level of aggregation of the Michigan data and with the ensuing equations having statistically insignificant coefficients.

Gujarati (1970). This study attempted to determine the ratio of electric space-heating customers to total residential customers using price of electricity, price of gas, personal income of the consumer, degree days, and number of housing units of various types. Multiple regression analyses were used for the period 1963-1967 for twenty-seven privately owned utilities. This study is not directly relevant because the concern in this energy alternative is the effect of deregulation on the demand for and supply of natural gas to all users, not just residential customers.

These six studies show widespread differences in the demand elasticity of natural gas. Each study has its problems and limitations, as pointed out by Draper, making reliance on any particular set of elasticities suspect.

Demand elasticity is analyzed in the six studies in terms of end users only. When considering deregulation of wellhead prices in terms of effect on supply-demand imbalances, supply and demand elasticities at the wellhead are more pertinent problems. None of the studies discuss these problems although wellhead demand is derived from user demand.

In summary, little can be said with assurance except that demand elasticity is negative. If the wellhead price of gas is deregulated, however, and the price increases 10 percent, any decrease in demand by pipeline companies in the short-run might be expected to be less than ten percent.

Supply elasticity.

Four recent studies have been made concerning price-supply elasticity. Some of the same problems arise in these studies as in the studies of demand elasticity, including level of aggregation of data, availability of relevant data, serial correlations, and proper identification of the supply function using significant variables from the data base. Although questions have been raised concerning the accuracy of these studies, the results have not been as divergent as those in studies of demand elasticity.

Garrett (1970). This study, using 1955-69 data, attempts to measure the resources that would become economically exploitable due to an increase in the wellhead price of gas, as distinguished from the amount that would be discovered. A constant elasticity-of-supply can be estimated of 0.5, indicating that a 10 percent increase in wellhead price would increase natural gas supply 5 percent.

Erickson and Spann (1971). An attempt was made, using 1946-59 data, to analyze the problem of joint costs, or the difficulty of separating gas well costs from oil well costs. They concluded that oil prices have no

long-range effect on gas supply and may, in the short-run, have a negative cross elasticity effect; in other words, an increase in oil price may decrease gas supply for a short period of time but is not expected to have an effect on gas supply in the long run. Their best estimate of gas supply elasticity was 0.5, with a 0.69 elasticity over the long-run.

Khazzoom (1971). This model, developed for the Federal Power Commission, does not estimate a constant elasticity-of-supply value. An equation based on 1961-68 data shows gas supply as a function of several variables, one of which is price. Assuming continuing regulation of the wellhead price, the supply-elasticity estimates vary from year to year.

MacAvoy (1971). Preregulation data in the period 1954-60 were used to estimate empirically a market clearing model, where supply, demand, and wellhead prices were hypothetically at a state of equilibrium. The model is then applied to 1961-67 data and the differences between actual reserve additions and wellhead prices, and the market clearing values are compared. These differences are assumed to be the result of lower supply at lower regulated prices. A supply elasticity value of 0.45 was obtained for the long-run.

Table 9

Supply Elasticity Estimates

Author and Date	Years for which data was analyzed	Supply elasticity
Garrett (1970)	1955-69	0.5
Erickson-Spann (1971)	1946-59	0.69 0.5 (best judgment)
Khazzoom (1971)	1961-68	No constant estimate
MacAvoy (1971)	1954-60	0.45

Thus, it appears that a 0.5 supply elasticity estimate might be a reasonable consensus of supply response to price. If the new average wellhead price is \$.27 per Mcf with reserve additions at 9.4 Tcf, an increase in price to \$.40 might raise available reserve additions 2.3 Tcf to 11.7 Tcf. This price amount must be modified by an estimate of demand elasticity. Unfortunately, it is difficult to obtain a consensus on demand elasticity since demand is established in reference to consumer as opposed to wellhead prices and since there is much variation in the available estimates. Thus, although an additional 2.3 Tcf might be available at \$.40 per Mcf, demand elasticities may have some effect on this price.

A report was issued recently by the American Petroleum Institute estimating the impact of alternative deregulation proposals on natural gas prices. The estimates were based on analysis of gas sales contracts in effect on January 1, 1973, varying assumptions as to market price levels in the event of deregulation and projections of "new" and "old" gas delivery volumes to 1980.

Delivery volumes and prices of "old" gas were projected to 1980 from volumes and prices payable under existing contracts for 2 Bcf or more annually. It was assumed that prices would rise to the estimated market level upon expiration of the contract and whenever contractual provisions would permit. The study estimates that as of January 1, 1974, 62 percent of the sales volumes under existing contracts would not be subject to escalation to the current market price. This percentage would drop to 48 percent by January 1, 1980.

With respect to "new" gas sales, it was assumed that new supplies would be committed at the market price and that annual reserve additions would increase from 10 Tcf to 19 Tcf by 1975 and 27 Tcf by 1980. The delivery volumes derived for "old" and "new" gas resulted in fairly stable production through 1976, increasing thereafter by approximately 2 percent annually.

The report noted that a positive relationship between supply and price was widely recognized, but that no technique had as yet been developed for reliably estimating the price elasticity of supply.

Projections of the impacts of deregulation at various market prices are summarized below:

Table 10

Estimated Average Field Prices, All Sales

	Deregulation of All Sales	Deregulation of New Sales and Expiring Contracts	Deregulations of New Sales Only
	(cents per Mcf)		
Assuming $.55 Market Price			
1/1/74	26.80	22.96	22.08
1/1/77	35.84	32.17	30.11
1/1/80	45.66	43.43	39.52
Assuming $.65 Market Price			
1/1/74	28.12	23.44	22.27
1/1/77	39.41	34.94	32.23
1/1/80	51.45	48.84	43.80
Assuming $.75 Market Price			
1/1/74	29.45	23.92	22.46
1/1/77	42.97	37.71	34.36
1/1/80	57.25	54.25	48.07

The above estimates compare with the average field price of 20.48¢ for all interstate gas deliveries as of 1/1/73.

The report has aroused considerable controversy; criticisms have been made that the report is misleading and deceptive in that market prices may rise considerably higher than the $.75 maximum assumed level in the report with greater costs to the consumer.

Environmental impact

An analysis of the environmental impact of the proposed deregulation of the wellhead price of gas has been prepared by the Department of the Interior in its draft environmental impact statement. As stated in the statement, this alternative would not result directly in any specific action. It would, however, trigger market forces which would result in increased activities impacting on the environment. These activities would center on increased domestic production, both onshore and offshore, of natural gas and associated oil. More detailed discussions of the impact of these activities are contained both in the draft statement on the proposed deregulation and elsewhere in this statement.

Oil Imports

Projections of future import levels

Oil imports will play an important role in fulfilling the rising demand for petroleum in the United States. The following table shows the expected increases in the demand for petroleum, the expected domestic production, and supplemental supplies that will be required to fulfill demand. If domestic production is not stimulated, the supplemental supplies shown in table 11 will come in the form of increased imports. After 1980, incremental production of petroleum products may be possible from such sources as oil shale, tar sands, and coal, but imports will still provide most of the supplemental supply.

Table 11

Total U.S. Petroleum Demand, Domestic Production and Supplemental Supplies Through the Year 2000 (in millions of barrels per day)

	1980	1985	2000
Total petroleum demand	20.8	25.0	35.5
Total domestic production	11.7	11.7	10.5
Supplemental supplies	9.1	13.3	25.0

Source: U.S. Department of the Interior 1972, United States Energy Through the Year 2000, by W. G. Dupree, Jr. and J. A. West, p. 43.

The National Petroleum Council analyzed energy supply and demand and provided projections of imports through 1985. Their projections were for four different sets of economic conditions, whereas Case IV represented the least favorable. Cases II and III were for conditions intermediate between the other two. The following table gives the National Petroleum Council projections of imports needed to balance demand for the four cases.

Table 12

Projected Level of Oil Imports
(in millions of barrels per day)

Case	1975	1980	1985
I	7.2	5.8	3.6
II	7.4	7.5	8,7
III	8.5	10.6	13.5
IV	9.7	16.4	19.2

Source: National Petroleum Council, 1972, U.S. Energy Outlook: A Report of The National Petroleum Council's Committee on U.S. Energy Outlook.

Another way to view projected oil imports is as a percentage of the total petroleum consumed or estimated to be consumed. In the four cases cited above the percentages of projected oil importation in 1985 are: Case I, 16 percent; Case II, 38 percent; Case III, 54 percent; and Case IV, 65 percent. These percentages demonstrate the increasing importance of imports when viewed against decreasing or constant domestic production and rising demand.

Present oil imports policies

Until President Nixon's energy message of April 18, 1973, imports of crude oil, unfinished oil, and oil products were limited under the Mandatory Oil Import Program established in 1959 by Presidential Proclamation 3279. In his message, the President stated that:

> "The Mandatory Oil Import Program was established at a time when we could produce more oil at home than we were using....Today, however, we are not producing as much oil as we are using, and we must import ever larger amounts to meet our needs. As a result, the current Mandatory Oil Import Program is of virtually no benefit any longer."

For this reason the President lifted controls and tariffs upon imports of crude oil, unfinished oils, and finished petroleum products; he imposed a gradually increasing scale of license fees on imports; and he provided for the reduction of the levels of most fee-exempt imports. Some fee-exempt imports that were intended to encourage exports of petrochemicals were continued. Under the quota system, the level of petroleum imports was restricted on the basis of petroleum product imported, the geographical area in the United States to which delivery was made, and for some imports, the country of origin.

The Office of Oil and Gas (or its successor agency) will continue to administer the oil import program. The license fees will be reassessed from time to time to be sure that the goals of stimulating domestic production and increasing refinery capacity are being met.

Import flow pattern

Sources of imports

In the past, the United States has received most of its imports from Western Hemisphere Countries. Because of declining resources and increasing domestic demand in these countries, they may not be able to meet future U.S. needs for imports.

Problems with the security of supply, balance of payments, and U.S. off-loading terminal capacity could arise due to an increase in imports from the Middle East and Africa. Using the 1972 Department of Interior projections of import levels, the following table (13) shows the breakdown of oil imports by source.

Table 13

Oil Imports by Source
(in million of barrels per day)

Source	1975	1980	1985 Low	1985 High
Western Hemisphere	2.3	3.0	3.3	3.5
Eastern Hemisphere	4.1	6.1	10.1	10.9
Total imports	6.4	9.1	13.4	14.4

Tanker and terminal requirements

In 1971, total tanker arrivals for the conterminous 48 states were 67,700. The projected rise of waterborne imports in 1985 to 10.7 million barrels per day would require expansion of United States port capacity.

A key factor in determining the changes that will be required in U.S. port facilities is the size of tankers delivering the oil. Since 1965, tanker construction has been directed almost exclusively toward vessels larger than 65,000 DWT. The development of successful single-point mooring systems, which allow the unloading of deep-draught tankers, and the closing of the Suez Canal in mid-1967, gave impetus to the construction of Very Large Crude Carriers (VLCC) ranging from 250,000 DWT to 425,000 DWT (presently under construction). A tanker of more than 700,000 DWT has been ordered and a 1,000,000 DWT vessel is in the preliminary planning stage.

The major attraction of large tankers is the reduction in unit transportation costs, as illustrated by table 14 below, for the major routes bringing oil to the United States. The savings possible by using larger ships for the longer distances are apparent. A 250,000 DWT tanker would save

$0.50/ton compared to a 65,000 DWT tanker on the Venezuelan route, whereas it would save $2.50/ton on the Persian Gulf route. As the volume of imports increases and as the primary source of imports shifts from Latin America to the Middle East, these savings will be important to the United States.

Table 14

Freight Cost of Transporting Oil
(Dollars per ton)

Ship size, in DWT	Round-trip distances in nautical miles 4,000	8,000	24,000
65,000	$1.90	$3.50	$9.05
250,000	1.40	2.50	6.55
326,000	1.25	2.30	6.15
500,000	1.00	1.90	5.45

Source: U.S. Department of Commerce 1972, Offshore Terminal System Concepts, Vol. 1, Fig. 1-32.

Balance of payments

Petroleum imports and associated activities have been important factors in United States deficit balance of payments. Imports of oil and refined products in recent years have equaled in value roughly seven percent of all imports. The petroleum industry has accounted for approximately 25 percent of U.S. net capital outflows and 33 percent of U.S. net earning abroad (National Petroleum Council 1972, p. 295).

Fluctuations in the value of the dollar and the international political situation affect import prices. At present the situation is too unsettled to make an accurate estimate of the effect on U.S. balance of payments. Another important factor in the balance of payments is secondary trade stimulated by

purchases of petroleum. U.S. dollars used to buy fuel or to finance overseas operations will generate return flows when the energy-exporting country spends part of its increased income on U.S. goods and services.

Security considerations

In 1970, a Cabinet Task Force on Oil Import Control made a comprehensive study of oil imports. The Task Force's report identified eight major security difficulties that might attend dependence on foreign supplies (Cabinet Task Force on Oil Import Controls 1970, p. 31).

1. War might possibly increase our petroleum requirements beyond the ability or willingness of foreign sources to supply us.

2. In a prolonged conventional war, the enemy might sink the tankers needed to import oil or to carry it to market from domestic production sources such as Alaska.

3. Local or regional revolution, hostilities, or guerilla activities might physically interrupt foreign production or transportation.

4. Exporting countries might be taken over by radical governments unwilling to do business with us or our allies.

5. Communist countries might induce exporting countries to deny their oil to the West.

6. A group of exporting countries might act in concert to deny their oil to us, as occurred briefly in the wake of the 1967 Arab-Israeli War.

7. Exporting countries might take over the assets of American or European countries.

8. Exporting countries might form an effective cartel raising oil prices substantially.

With the creation of OPEC, the last point, formation of an effective cartel, has already occurred. The result, as the study had foreseen, has been a substantial increase in oil prices.

The basic problem with importing a substantial proportion of the nation's oil is that the sources of additional foreign oil--in general, the Middle East and North Africa--are not firmly committed and oil exports to the United States might be withheld for political and/or economic gain.

Schurr and Homan (1971) note that the question of supply interruptions

> ". . . needs to be dealt with in the interests of both the importing and exporting countries because supply interruptions are economically damaging to both. Not only do they have sharp short-run effects which are economically painful, but their longer-run consequences can also be damaging if channels of commerce are diverted into alternatives which impose a permanent economic penalty upon both those countries that sell oil and those that buy."

Interdependence of exporting and importing countries does not guarantee that interruptions will not occur. Schurr and Homan (1971) point to interruptions from the shutdown of Iranian production beginning in 1951, the closure of the Suez Canal and attendant lengthening of transportation routes in 1956-1957, and again from 1967 to the present.

The Cabinet Task Force on Oil Import Control (1970) identified three possible alternative measures to cope with an interruption of supply. These are: use of synthetic sources of crude, such as oil shale or tar sands; development of the shut-in capacity of Naval Petroleum Reserve No. 4; and provision to store oil until needed. The last of these alternatives is discussed below; the others are discussed elsewhere in this statement.

The most promising methods of storing oil are in steel tanks or in salt domes. Estimates made in 1970 of the capital costs of storage in steel tanks range from $1.84 per barrel to $2.75 per barrel, including land acquisition. Annual management and repair costs would be 11 to 14 cents per barrel. Evaporation losses in a cone-roof tank would be about two percent.

If a floating roof were used, evaporation losses should be negligible (Cabinet Task Force on Oil Import Control 1970, p. 299).

Salt domes presently are used in the United States for the storage of natural gas liquids. A study by the Department of the Interior indicated that in 1966, 130 unused onshore salt domes were suitable for storage in the Gulf Coast area (U.S. Bureau of Mines 1966). A potential storage capacity of five million barrels was assumed at each site, yielding a total capacity of 650 million barrels. The capital cost of storage in salt domes was estimated to be from $1.02 per barrel to $2.04 per barrel. Because there would be no evaporation loss and only minor maintenance and management costs, total annual costs would be low. There would be some loss of oil in the recovery process, estimated to be five percent.

Imports in the short run would have to be increased to obtain the crude oil for storage. These imports would either go directly into storage or would replace domestic crude oil, which would be stored.

Environmental impact

Additional ship traffic and oil handling made necessary by increased imports will have the environmental impacts discussed below.

Potential oil pollution

Three factors are considered in analyzing possible oil pollution related to tanker shipment of imports: (a) intentional discharge, (b) accidental discharge, and (c) tanker casualties.

The primary sources of intentionally discharged oil are shoreside ballast-treatment facilities and underway tank-cleaning operations. Ballast-treatment facilities would be maintained in foreign waters at the loading end

of the system. It may be assumed, therefore, that all intentionally discharged oil in U.S. waters will come from tank-cleaning operations.

Accidental discharge includes all unintentional oil spills except those caused by tanker accidents. According to Pollution Incident Reporting Systems (PIRS) data, approximately 0.0015 percent of the oil handled in the U.S. in 1970 was spilled during transfer operations (U.S. Coast Guard 1972). Applied to the projected through-put for 1975, 1980, and 1985, this rate of spillage would result in spills of 61 barrels per day, 91 barrels per day, and 160 barrels per day, respectively.

About 0.00009 percent of the oil handled was accidentally discharged in 1970 in restricted waters surrounding harbors and ports (U.S. Coast Guard 1972). This rate of spillage amounts to spills of 3.7 barrels per day in 1975, 5.5 barrels per day in 1980, and 9.6 barrels per day in 1985. In response to pressure from regulatory agencies, there has been recent action to prevent accidental spills, including safety backup systems, training of personnel, routine inspection, and mandatory reporting of accidental spills.

An insignificant amount of the total volume of all oil transported by tanker is spilled, exclusive of transfer operations. The environmental impact could be nominal for small spills or where the spilled oil will not drift ashore. A single catastrophic incident, however, such as the breakup of the _Torrey Canyon_ can have disastrous results. The oil-spill problem is a subject receiving considerable study. The first report on the President's Panel on Oil Spills gives many details relative to the subject.

Increased tankers and terminals

Increased petroleum imports will require an increase in the number and/or size of tankers. The heavily populated Northern Atlantic coastal

region will be the primary destination of petroleum shipments, and the Gulf Coastal region will be the secondary destination. If the use of conventional ports continues, tankers will be restricted to 60,000 DWT or less. The continued use of these small tankers will require a large increase in the number of tankers unloaded each day. The added congestion would increase the risk of collision and subsequent oil pollution. The transfer of oil from VLCCs to small tankers at foreign ports would also cause substantial increases in ship traffic. The problems of port congestion could be alleviated by the use of large tankers making deliveries directly to U.S. terminals.

The environmental impacts of building terminals to handle large tankers will be determined by their locations. Enlarging channels and harbors of existing ports would require dredging which could endanger sensitive estuarine areas. These areas are important as nursery grounds for many aquatic animal species and for a variety of recreational pursuits. Extensive dredging also presents the danger of penetrating freshwater aquifers and causing saltwater contamination of nearby urban water supplies. Expansion of existing port facilities in populated areas could cause conflicts with existing or planned land uses.

Offshore terminals would greatly reduce the dangers of dredging and port congestion. The determining factor would be the distance of the facility from shore. Terminals close to shore would generally require dredging. Maintaining a close-in facility could, therefore, cause some damage to estuarine areas as a result of dredging and of oil spills that could reach shore before dispersing or being cleaned up. A terminal farther offshore might not require dredging and would allow spills to disperse or be cleaned up before reaching sensitive areas.

The construction of a breakwater or island would permanently eliminate from productivity the area of sea floor covered by the structure. Some of this lost area, however, will be offset by fish havens formed by rubble mounds. A deep-water site would affect fewer species than one in shallow or moderately shallow water. A breakwater could reduce wave action at the shoreline and thereby reduce beach erosion. This could lead to the deposition of suspended sediments and accretion of the beach. Continued accretion could cause the development of a sand spit which might ultimately extend to the offshore structure. If accretion took place at the up-current end of the beach system, the normal supply of sand to the rest of the beach would be cut off and the beach might become silty or muddy. Generally, if the distance from the structure to the shore is more than twice the length of the structure, the effect on the shoreline would be slight (Department of Commerce 1972, p. 19).

Pollution potential at loading site

The increased movement of petroleum will result in increased probability of oil spills at the loading end. Additional spills would result from intentional and accidental discharges and from tanker casualties such as collisions and groundings. In some exporting countries where pollution control standards may not be stringent, the potential for pollution would be appreciable.

Relationship of alternative to proposed mining in the Eastern Powder River Coal Basin

Under this alternative, the replacement of the total energy expected from mining through 1990 would require additional oil imports of about 4,567 MM Bbl (26.5 Quintrillion Btu).

Importing petroleum would have a negative impact on the United States balance of payments. Some of the factors affecting this impact are: the type of import; that is, crude oil, semi-refined products, or refined products; the price of imported oil; the exporting countries' propensity to import from the U.S.; the amount of U.S. capital invested in the exporting country for these facilities; and the nationality of vessels carrying the oil. In the past, imported petroleum was generally less expensive than domestically produced petroleum. Recent events, such as the devaluation of the U.S. dollar and agreements that allow greater participation of the exporting countries in oil production have brought the price of foreign oil delivered to the U.S. to a much greater cost than that of oil produced domestically; and, this price gap is unstable and subject to daily change making predictions unreliable. Thus, increased oil imports do not constitute a viable alternative for mining in the Eastern Powder River Coal Basin.

Natural Gas Imports

Domestic production of natural gas will have to be supplemented to fill energy needs. The supplements will be synthetic gas from coal and liquid hydrocarbons, and natural gas imports. Synthetic gas is discussed in a separate section. Natural gas could be imported into the United States by pipeline from Canada or Mexico or by tankers from other countries in the form of liquified natural gas (LNG).

Pipeline natural gas imports

Pipeline imports of natural gas comes into the United States from Canada and Mexico. In 1972, 1.0 tcf (trillion cubic feet) were imported from Canada, and 0.0008 tcf came from Mexico. Mexico has a small proven natural gas supply base and a policy of self-sufficiency in energy. Present contracts expire in 1982; thus, if no new supplies are released for export, imports from Mexico could practically cease at that time. Increases in pipeline imports of natural gas would therefore come from Canada.

Future increases in natural gas exports from Canada may be limited by the Canadian National Energy Board (NEB). In November, 1971, the NEB dismissed three applications for licenses to export over a 15- to 20-year period nearly 2.7 tcf of gas to the U.S. The NEB rejected the applications because ". . . the Board decided that there was no surplus of gas remaining after due allowance had been made for the reasonably foreseeable requirements for use in Canada . . . ." (Canadian National Energy Board).

Liquified natural gas (LNG) imports

Because of the growing shortage of domestic gas supplies, plans are now being made by the gas industry for liquified natural gas (LNG) imports

under long-term contracts. LNG imports cannot be quickly increased to meet the demands for greater supplies of natural gas. Large-scale shipping of LNG is a relatively new industry and the United States does not yet have facilities for receiving large shipments. The Federal Power Commission recently approved two projects which together call for deliveries of the equivalent of more than one billion cubic feet per day of LNG. Several other projects have been proposed and are pending approval. Future import levels will depend on the rate of growth of the United States' LNG industry.

Economic considerations

The impact that LNG imports will have on the United States balance of payments is difficult to assess fully. Capital from the United States will undoubtedly be required for part of the cost of construction of foreign-based liquefaction plants. The Export-Import Bank, for example, is providing some of the money necessary for the construction of an Algerian plant. It has not been established, however, just how much U.S. capital will move to exporting countries or how much will return through the purchase of U.S. equipment. The use of foreign or domestic tankers will also affect the balance of payments. The cost of the gas itself will, however, probably have the greatest impact on the balance of payments. One estimate of the f.o.b. price of gas is \$0.38 to \$0.53 per thousand cubic feet (Khan and Budle 1972). Importing 1 tcf could, therefore, result in an outflow of \$380 to \$530 million. It should be noted that the various potential source countries have a wide range of propensities to import goods and services from the U.S.

The price to the consumer of imported LNG is also difficult to project. The FPC, is approving the El Paso Natural Gas Company application to import LNG, limited initial prices to \$0.77 per million Btu's (British thermal units)

delivered to Cove Point, Md., and $0.83 at Savannah, Ga. The company has indicated that the allowed prices may be insufficient. In 1973, prices for natural gas in the United States, under the area rate method, ranged from $0.225 to $0.34 per mcf at the wellhead. Under the FPC's new optional pricing system, the price of new gas is higher. The first applicants under this policy have proposed to sell gas for prices as high as $0.55 per mcf.

Environmental impacts

Increases in tankers; increases in terminal, transfer, and regasification facilities; and the transportation and combustion of imported gas would all have environmental impacts in the United States.

Any seagoing vessel may be involved in collision or other mishap; however, escape of LNG to the environment from a ship would not necessarily have a seriously adverse impact. Because LNG remains liquid only below $-259^{\circ}F$ at atmospheric pressure, any spilled LNG would immediately begin to vaporize but, although it would pollute the air, it would have little impact on land or water resources. Studies on the possibilities of explosions resulting from LNG spills are inconclusive.

Each regasification plant will require facilities to permit the transfer of LNG from tankers to storage areas. At Cove Point, this will be accomplished by the construction of a mile-long pipeline into Chesapeake Bay. At the proposed Savannah plant, a channel and a turning basin would be dredged in the Savanna River to allow the tankers to come close to the plant. Both methods will require initial dredging, possibly require continued dredging, and will cause increased turbidity of the water. The dredging and turbidity will disrupt the habitat of marine animals, especially sessile bottom-dwelling organisms. Most of the disruption would be temporary but as much care as

possible would have to be taken to avoid contaminating commercial fishing areas. The potential for fire or explosion is always present during the transportation, transfer, or storage of LNG. Because spilled LNG would not vaporize instantaneously, the release of the equivalent of several million cubic feet of gas, for example, might cause a fire which could continue until all the LNG had vaporized. An early LNG plant was destroyed by a disastrous fire in 1944 due to the failure of a storage tank, with a loss of more than one hundred lives. Since then, many improvements have been made in LNG storage and handling technology and increased attention has been given to proper safety precautions. However, a recent explosion of a Staten Island storage tank, killing more than 40 men, shows that there is still an element of danger involved in the storing and handling of LNG.

The construction of regasification plants will have impacts on land resources. The extents and durations of the impacts will depend on the sizes and locations of plants. For example, the plant proposed for Cove Point, Md., would produce initially 650 mcf of gas per day and require a 1,022-acre tract of land; another plant proposed for Savannah, Ga., would produce initially 335 mcf of gas per day and require 860 acres. During construction there would be some disruption of the land surrounding a plant and some damage to animal habitats. The damage will be permanent only in the area occupied by a plant and supporting facilities.

Very few pollutants will be released to air or water in the processes used to regasify the LNG. Plants using water to regasify LNG will release the water at a lowered temperature. For example, at the Savannah plant, the temperature of water returned to the river will be lowered 5°F.

A regasification plant could have an impact on the scenic and recreational resources of an area. Thus, the choice of a plant site is an

important factor in minimizing the impact on scenic qualities and recreational activities. An increase in ship traffic could have an effect on water-oriented recreational activities.

Because natural gas is a clean-burning fuel, the impact of combustion on air quality would not be appreciable. Water and carbon dioxide are produced in burning, and both can be harmlessly dissipated.

LNG imports will require the construction of new pipelines between regasification facilities and existing pipeline distribution systems. Pipelines generally are buried several feet underground, except for necessary pumping stations and control valves. The impact on scenic qualities and recreational activities is thereby minimized or eliminated. Rights-of-way would have to be established and kept cleared of structures and vegetation that would interfere with operation and maintenance of the systems. Trenches dug for the pipe would be narrow, and the damage would be temporary.

Relationship to mining coal in the Eastern Powder River Coal Basin

Importing natural gas as an alternative to mining coal in the Eastern Powder River Basin would require additional imports equal to the energy expected from the Basin. Projections of future natural gas import levels, made in 1973, indicated a maximum level of imports (total U.S.) of 3.9 tcf per year in 1980 and 6.8 tcf per year in 1985.

Any near-term increases in the amount of natural gas imported by pipeline would have to come from Canada. At the present time, the policy of the Canadian government has been to build a large domestic reserve by restricting the level of gas exports. Unless this policy changes, it is unlikely that the necessary gas would become available.

Increases in LNG imports depend on how quickly the LNG industry can be introduced into the U.S. At the present time, the U.S. has no LNG projects in operation, although one has been approved and others are pending approval.

Coal (Nationwide)

The purpose of this description of the nation's coal resources and industry is to place in perspective the amount of coal which can be produced in the Eastern Powder River Basin and the environmental impact of mining the coal elsewhere.

Coal resources and reserves

The nation's coal reserves are more than adequate to support an accelerated schedule of development for many years. Coal is the nation's most abundant fossil fuel. It contains on a Btu basis about 89 percent of the identified energy resources, as compared to 5 percent for natural gas (dry), and 6 percent for oil (including natural gas liquids) (U.S.Geological Survey 1969, p. 90).

Coal underlies 458,600 square miles in 37 states. The coal resources of the nation were estimated to total more than 3,200 billion short tons as of January 1, 1967 (U.S. Geological Survey 1969, p. 13). Of this amount, 2,800+ billion tons were estimated to be at depths of less than 3,000 feet and nearly 1,400 billion tons were estimated to be at depths less than 1,000 feet. Slightly more than 1,500 billion tons have been identified by mapping and exploration. About 200 billion short tons of all types of coal are commercially recoverable under present economic conditions and mining technology and are considered the recoverable reserve (U.S. Bureau Mines, January 1, 1972, unpublished data). The remaining coal resources in the Rocky Mountains and Great Plains were estimated to be 874 billion short tons as of January 1, 1967 (U.S. Geological Survey, p.33), including 188 billion tons in beds 10 feet or

more thick and less than 1,000 feet below the surface. The recoverable resource of low-sulfur coal in the nation is about 94 billion tons to a depth of 1,000 feet.

Approximately 84.5 billion tons of recoverable resources in the Rocky Mountain and Northern Great Plains provinces can be extracted by surface mining. About 25 billion short tons of low-sulfur coal are considered the strippable reserve (Bureau of Mines 1971a, p. 15). Of the 45 million tons of coal produced west of the Mississippi River in 1970, 33 million tons were low-sulfur coal, 78 percent of which was mined by surface operations.

Due to environmental standards on sulfur emissions, high sulfur coal will not be minable after January 1, 1975. It is generally accepted that this will create a shortage of coal supply in relation to demand in 1975 and beyond until new mines can be opened to produce low-sulfur coal. The degree of the shortage is at present unknown. The upcoming situation will cause a high demand for low-sulfur western coals.

About one-half of the remaining coal resources in the West underlie the northern part of the Great Plains in very thick and closely spaced beds of lignite and subbituminous coal. The coal generally has a low-ash-fusion temperature, a low-sulfur content, a relatively low heating value, and a high content of volatile matter. This coal is adaptable for power generation, gasification, and liquefaction, particularly where strip mined at low cost.

Northern Great Plains Resource Program

The Department of the Interior announced on October 3, 1972, a Northern Great Plains Resource Program (NGPRP). The Northern Great Plains, which includes large parts of Montana, Wyoming, North Dakota, South Dakota, and Nebraska, has been the focus of increasing attention because the area contains vast amounts of relatively low-sulfur coal. The possibility of large-scale development of the coal resource has heightened concern for effective land use and resource planning, including such

issues as environmental quality, mined-area reclamation, competition for scarce water resources, development of other mineral resources, and potential effects on the population and economics of the Northern Great Plains States.

The local, State and Federal Governments which make land-use and resource-planning decisions affecting the Northern Great Plains area face competing economic, social, and environmental alternatives. The Federal Government makes decisions regarding leasing schedules for coal resources on public and Indian lands, regulations for air and water quality, and development of water projects. Congress is considering several measures related to strip mining. The states also are concerned with resource development; many have considered or taken legislative action related to strip mining and have prepared State Implementation Plans for air quality under the Clean Air Act. Local governments promulgate zoning and land-use plans and provide for essential public services. Regional Commissions for economic development and water supplies share similar concerns and responsibilities. These overlapping local, state, regional and national interests are not well-coordinated at this time.

These factors have led the five states, the Old West Regional Commission, and several federal agencies to initiate cooperatively the NGPRP in order to bring together and coordinate information that bears on the future development and environmental quality of the region.

The NGPRP is designed solely to examine the possible consequences of alternative development plans of the resources of the region, including, but not limited to, coal. The purpose of the program is not to recommend actions or make decisions but rather to display the facts and the implications

of various alternative plans upon the social, economic, and environmental future of the area. The end result is intended to be a decision-making tool for federal, state, and local interests who together must plan and manage the area's land and natural resources.

The principal issue concerns the development, or nondevelopment, of land and mineral resources within the Powder River and Fort Union areas. Particular emphasis is placed on coal resources. The program will provide data and analytical methodology, including the development of appropriate models, to demonstrate the economic, social, and environmental consequences of various courses of action. The program will present both quantifiable and nonquantifiable implications of alternative land and resource uses.

Environmental impacts of coal utilization

The expanded use of coal for power generation is a viable alternative to the use of less abundant fossil fuels (oil and gas). Major limiting considerations are the extent to which coal can be substituted for other energy sources, including the convertibility of equipment where displacement would be involved, and the problem of maintaining air quality near plants that burn coal.

The sulfur content of U.S. coals ranges from 0.2 to over 7 percent. About 65 percent of the nation's identified resources contain 1.0 percent or less sulfur. Most of these resources are in the Western States far removed from the major markets of the Midwest and East (Bureau of Mines 1966b, p. 8). The bulk of current coal production is from states east of the Mississippi River where low-sulfur coal is in short supply and medium- and high-sulfur coal are more abundant.

Sulfur oxides generally are emitted to the atmosphere in direct proportion to the sulfur content of the coal feedstock. Recent environmental regulations applicable to new electric generating facilities restrict the emission of sulfur dioxide to 1.2 pounds per million Btu of fuel as fired. For bituminous coal, this is equivalent to about 0.7 percent sulfur. In most areas, if coal is to be used for power generation, implementation of the regulations requires that the sulfur content of the coal be reduced prior to burning or that the sulfur oxides be removed from stack gases following combustion.

Mechanical cleaning of raw coal is only a partial solution to the problem because only a small fraction of American coal can be cleaned sufficiently to meet sulfur standards. Mechanicial cleaning removes only pyritic sulfur and leaves untouched the 40 to 60 percent of the sulfur that is chemically combined in the organic structure of the coal. Freeing small particles of pyrite requires fine grinding prior to cleaning, which in turn adversely affects cleaning efficiency and restricts the methods of cleaning that can be used. Tests of some 322 coals representing most of the steam coals produced in eastern United States showed that regardless of the fineness of grinding, and utilizing present cleaning technology, less than 20 percent of these coals could be cleaned to 0.7 percent sulfur prior to combustion (Bureau of Mines 1971a).

The status of technology for flue gas desulfurization (FGD) was reviewed at a special public hearing in Washington, D.C. from October 18 to November 2, 1973. The Environmental Protection Agency position (Report of the Hearing Panel - National Public Hearings on Power Plant Compliance with

Sulfur Oxide Air Pollution Regulations; EPA; January 1974) stated at these hearings inlcuded the following:

(1) FGD technology represents a viable means of achieving power plant SO_2 control.

(2) Technological feasibility of FGD systems has been established.

(3) A large fraction of the nation's coal-fired power plants can be fitted with commercially available FGD systems and meet SO_2 control requirements.

Some of the optimistic assessments of economics of stack-emission controls are based on receiving a substantial credit for sale of byproduct sulfur, but the supply of sulfur, recently, has exceeded demand, and substantial additional production of elemental sulfur could cause further disruption of the domestic sulfur industry.

President Nixon in his June 4, 1971, message to the Congress on Clean Energy emphasized the need for a greatly expanded effort on sulfur oxide control technology. Federal funding is being directed to demonstrate various techniques during the next several years. The Environmental Protection Agency has issued regulations restricting use of high-sulfur coals effective January 1, 1975.

Comparison with mining in Appalachia

In 1973 about 65 percent of all coal mined in the United States came from Appalachian coal fields. In past years most of the low-sulfur (less than 1 percent sulfur by weight) coal produced in the United States came from Appalachia despite the fact that Appalachia contains only 18 percent of the coal resources of the country. Presently identified recoverable reserves in Appalachia are about 22 billion tons of coal of which about 5

billion tons are available strippable reserves and 17 billion tons available chiefly by underground mining methods. About 12 billion tons are low-sulfur coal of which about 1.9 billion tons are strippable.

Coal in Appalachia is mostly bituminous in rank which yields about 11,500 Btu per pound. About 0.748 tons of Appalachian coal will yield the energy equivalent of one ton of coal from the Powder River Basin (assuming 8,600 Btu per pound for subbituminous coal). Large tonnages of coal from both Appalachia and the Eastern Powder River Basin will meet the EPA standards for sulfur emissions from stack gases at electric power generating plants. Almost all low-sulfur bituminous coal in Appalachia has coking characteristics and is valuable for its metallurgical uses, particularly in the manufacture of steel. Some medium- and high-sulfur coal of Appalachia can be cleaned and blended with the low-sulfur coal to produce metallurgical coke also. Nearly half of the low-sulfur coal presently mined in Appalachia is used to produce metallurgical coke; the other half is used mainly by electric utilities and by industry and retail dealers. About 40 to 50 million tons of metallurgical quality low-sulfur coal produced in Appalachia is exported from the U.S. yearly. Low-sulfur coal that is transported to the Midwest and South from Appalachia, of which about half is used to produce coke and half to produce electricity, amounts to only 26 percent of the total Appalachian production. Subbituminous coal from the Powder River Basin is not of coking quality and has no value as metallurgical coal. Future unlimited use of Appalachian metallurgical quality coal for power generation instead of Eastern Powder River Basin coal would be considered a misuse of a valuable resource.

All producing mines and mines now being developed both in Appalachia and in the Eastern Powder River Basin have a ready market for low-sulfur coal

because of the high demand for such coal (to be used in newly constructed power plants and older plants converting from use of higher sulfur coal or other fuels) in order to relieve the energy crisis, clear up the environment, and make the Nation energy self-sufficient. Increased export of coal, especially metallurgical coal from Appalachia, has been suggested as a means to help balance payments of trade deficits.

The impacts on the coal-based economy of Appalachia (including the coal-transporting railroads) should be slight if coal of the Eastern Powder River Basin is mined and transported to power plants in the Midwest and South. Only marginal mines without proper coal preparation facilities may lose markets to the competing western coal; however, even this may be compensated by the anticipated increased demand for low-sulfur coal from both east and west.

When compared to coal production from surface mines in the Eastern Powder River Basin, coal production in Appalachia has the marketable advantages of coal with higher heat value, nearness to markets, less costly transportation, and an established industry with distribution facilities. Conversely, Appalachian coal is more expensive to mine and has less flexibility to production schedules because it must be mined by underground methods or in limited strip mine and auger areas in mountainous terrain. In areas where the markets for western and eastern coal may overlap, the deciding factor on which contracts are signed might well be the quarantee of delivery of coal, which would be more easily satisfied by immediate increased production by the western producer.

The coal industry and the related economy of Appalachia may undergo a boom if it must supply the low-sulfur coal in lieu of production from the Powder River Basin. Appalachia presently produces about 390 million tons of coal

per year. An additional 100 million tons per year production by 1987 (equivalent to 134 million tons of coal from the Powder River Basin) as the alternative fuel source would transfer the environmental impacts of mining coal from Wyoming to Appalachia. Part of the Appalachian production will necessarily have to shift to low-sulfur coal to replace the present production of medium- and high-sulfur coal that cannot be cleaned to meet EPA standards for sulfur emissions at power plants. Much of the Appalachian coal which might be produced would have to come from underground mines where coal production efficiencies are less than surface mines, the costs of mining are higher, and dangers of mining are greater. Production from existing underground mines would have to be expanded immediately, if possible, to meet the demand, for development of new underground mines would require as much as five years. Even if the immediate demand were met by strip mining, the impact would be magnified to some extent because Appalachian coalbeds are on the order of 15 feet thick or less, thus demanding that about 4.5 times as large an area be stripped or mined underground for an equivalent tonnage of coal.

Coal transporting railroads will be hard pressed to increase traffic on existing lines in Appalachia and to obtain rights-of-way to build new lines to distribute the increased coal production. Secondary impacts at power plants would be increased if coal, with unacceptable sulfur content, is allowed to be produced in Appalachia to meet the increased demand rather than to develop the Eastern Powder River Basin coal.

Nuclear Power

Technological processes

One of the most important advances in the electric power industry in the past few decades has been the development of nuclear energy for power generation. Nuclear reactors are of two types: "thermal" and "fast". Thermal reactors, including the light-water reactors, employ moderating materials to slow the neutrons before most fissioning occurs; in fast reactors, fission is produced by neutrons of much higher energy levels. The fast reactor offers the possibility of using a much greater part (estimated 60 percent) of the potential energy in uranium ores.

The nuclear system common in the U.S. is fueled by uranium dioxide, moderated and cooled by light water; this system produces most of the electric power generated by nuclear fuels in the U.S. today. It is expected to dominate nuclear power generation during most of the next decade. The heat energy created by nuclear fission in this system is removed by the circulation of water through the fuel core. As the water circulates, it is transformed into steam which turns turbine generators. The water thus functions as a coolant to transport the heat released during fission and as a propellent for the turbines. In addition, light water is used as a moderator to slow down the fast neutrons produced by fission. Fuel consists of slightly enriched uranium dioxide pellets encased in tubing of a zirconium alloy. The fuel rods are assembled into bundles. Control rods are strategically placed in the fuel to regulate the rate of the nuclear reaction.

Specific operations in the light-water reactor fuel cycle include the following:

1) Mining uranium ore.
2) Processing the ore to produce uranium concentrates.
3) Production of uranium hexafluoride from uranium concentrates to provide feed for isotopic enrichment.
4) Isotopic enrichment of uranium hexafluoride to the level required using the gaseous diffusion process.
5) Fabrication of nuclear-reactor fuel including converting uranium hexafluoride to uranium dioxide, pelletizing, encapsulating in rods, and assembling fuel elements.
6) Production of power from the reactor.
7) Reprocessing irradiated fuel to recover plutonium, produced and unburned uranium, and converting the uranium to uranium hexafluoride for recycling through the gaseous diffusion plant and reenrichment.
8) Radioactive waste management of high-level and other wastes, including long-term storage of wastes.
9) Transportation of materials to and from places where each of the above operations takes place.

Resource base

The Atomic Energy Commission maintains two types of estimates of uranium resources. The first of these is for "reserves", which is uranium in known deposits that can be economically and technologically produced. The second estimate is for "potential resources", which is

additional uranium that may exist in unexplored extensions of known deposits or in undiscovered deposits within or near known uranium areas. These estimates do not represent the total uranium resources of the U.S. because other uranium areas undoubtedly exist and will be discovered in the future. However, discovery of new deposits outside known mining areas may be difficult and expensive. Each resource category is also qualified by cost. Estimates at lower costs are more precise because they are based on better data from industry exploration, which has focused on lower-cost reserves.

Reserves of U_3O_8 producible at \$8 a pound are 178,000 tons, about 50 percent of which is found in New Mexico, 35 percent in Wyoming, 5 percent in Texas, 3 percent in Colorado, and 3 percent in Utah. The remainder is scattered throughout the rest of the western U.S. As of the beginning of 1972, the AEC estimated that reserves of U_3O_8 producible at \$10 a pound in conventional deposits in the western U.S. (including 178,000 tons of \$8 per pound U_3O_8 reserves) were 337,000 tons. Potential resources of U_3O_8 in the western U.S. were an additional 450,000 tons producible at \$8 and 700,000 tons producible at \$10. In 1972, approximately 42 percent of U_3O_8 production came from New Mexico, 33 percent from Wyoming, 7 percent from Colorado, and 6 percent from Utah.

Economic considerations

Adequacy of uranium reserves depends on the resource base and time-frame being considered. A large gap between long-term uranium requirements and resources is apparent if resources are confined to the

U_3O_8 reserves producible at $8 per pound. This gap narrows progressively with the inclusion of $8 per pound potential resources, $10 per pound reserves, $10 per pound potential resources, and so on. If short-term demand is considered, reserves producible at $8 per pound are about equal to the next 10- to 11-year requirements.

Uranium at costs of $15 per pound may be economically competitive in water reactors in the future. The uranium content of $15 resources ranges from 0.10 to 0.12 percent U_3O_8 compared to 0.20 to 0.22 percent for $8 resources. Therefore, almost twice as much ore must be mined and processed to produce an equivalent amount of uranium. Mining and milling capacity would have to be doubled to maintain existing U_3O_8 production levels.

Capital costs of nuclear power plants have increased in the past few years. The AEC has developed a method to estimate costs for a specific power plant on the basis of a reference case cost (Olds 1973). A detailed cost model is selected and modified using data input for the specific project. The model case may be broken down into more than one hundred cost accounts, each of which can be adjusted separately. Using this procedure the following estimates were developed for the base capital cost of a 1000-megawatt (MW) pressurized water reactor reaching commercial operation in 1980.

Table 15

Capital Costs of a Nuclear Generating Station

Category	Cost in millions of dollars
Structures and site facilities	38
Reactor/boiler plant equipment	59
Turbine plant equipment	68
Electric plant equipment	16
Miscellaneous plant equipment	5
Total Direct Cost	187
Contingency allowance	12
Spare parts allowance	1
Indirect costs	49
Total Mid-1972 Cost	249
Escalation to start of construction	---
Total at Start of Construction	249
Interest during construction	63
Escalation during construction	99
Total at Commercial Operation	411
Allowance for cooling towers	20
Allowance for near-zero radwaste system	4
Allowance for SO_2 removal system	---
Total cost at Commercial Operations in 1980	435

Escalation rates are 5 percent per year for equipment and materials and 10 percent per year for site labor.

Source: F.C. Olds, ed "Capital Cost Calculations per Future Power Plants", compiled from AEC source material and summarized in Power Engineering (1973).

Installed nuclear capacity is currently 17,000 MW. The AEC anticipates that capacity will increase to 52,000-57,000 MW by 1975, 127,000-144,000 MW by 1980, and 256,000-332,000 MW by 1985.

Environmental impact

Impacts on air quality

Nuclear power plants, unlike fossil fuel plants, do not emit the usual products of combustion such as particulates, sulfur oxides, and nitrogen oxides. However, they do produce radioactive emissions which must be strictly limited to avoid adverse health affects.

In the normal operation of nuclear generating units, small amounts of radionuclides are discharged in the cooling water and gaseous effluents. Present standards limit the release of radio-activity so that the average additional annual dose is three to four orders of magnitude less than the average annual level of natural radiation exposure. Thus, the effects of the amounts released are likely to be negligible.

Impact on water quality

The operation of light-water reactor plants generates considerable amounts of waste heat due to low thermal efficiency (about 33 percent compared to 40 percent for new coal-fired thermal plants). A light-water reactor releases approximately 50 percent more waste heat into its cooling water than a fossil-fuel plant of similar capacity (Resources for the Future 1971, p. 19.). The effects of waste heat depend on many factors including the cooling method used and the location of the plant.

Assuming a 15° to 20°F temperature rise in the cooling water, a "once through" direct discharge of cooling water requires 250 to 360 billion gallons of water per year for 1,000-MW plant. The effects of such discharge depend on the size of the body of water into which the heated water is discharged. The intake of large amounts of water from streams can have seriously disruptive effects on their flow regimes.

In smaller lakes and rivers or in bays with limited circulation, the discharge of heated water may result in fish kills, interfere with reproduction of aquatic biota, disrupt food chains, decrease dissolved oxygen content, displace desirable aquatic species, and encourage growth of undesirable algae, which may accelerate eutrophication. However, at some places the heated water can be used for aquaculture and other beneficial uses. Cooling ponds and cooling towers produce haze, fog, cloud and ice formation during periods of subfreezing temperatures.

Impact on land

Uranium mining is now concentrated in relatively isolated semidesert areas distant from large population centers. In 1972, 40 percent of the uranium production came from underground mines; most of the remainder was from open pit mines. Surface mining disturbs a few hundred acres for each mine and reduces the suitability of the area for grazing, wildlife, and some types of outdoor recreation. Underground mining requires accumulation of waste rock in dump areas but causes less surface disturbance than open pit mining. For either

type of mining, careful planning for post-mining land use, including environmentally acceptable reclamation, can substantially reduce land-use problems.

Because of the low concentration of U_3O_8 in uranium ore and the difficulty of complete extraction of uranium in milling, tailings are radioactive at a low level and must be stored above ground or replaced at the mine. Radioactive tailings are potentially dangerous if used for fill material under buildings or other structures where people live or work. Tailings stored above-ground can be covered with gravel or dirt to minimize erosion and leaching. Other use of storage areas should be restricted or prohibited for many years.

Under current siting criteria, nuclear plants are isolated from population centers. The construction of three 1,000-MW units per site for 3,000 MW of nuclear capacity requires about 500 acres from which most other uses are excluded. If the plant recirculates cooling water, an additional acreage estimated at 1,000 to 2,000 acres per 1,000-MW unit is required for water storage.

Transmission-line rights-of-way require the use of ten to fifteen acres per mile of line. Land adjacent to transmission lines may be available for other purposes, such as recreation. Although transmission lines disrupt scenic vistas at many places, they are required whether the electricity is produced by nuclear, hydropower, or fossil fuel plants.

Control of radioactive emissions

Risk of accidents

In the operation of nuclear plants, there is some risk of accidents; however, the plants are designed to minimize accidents by utilizing a "defense-in-depth" principle. Reactors are built in remote areas and designed to confine their effects to the vicinity of the plants. All nuclear plants are designed to withstand the worst malfunction for which corrective action can be planned. For light-water reactors, the worst accident is a major rupture in the primary cooling system. The maximum radiation dose that could be received at the site boundary, if such an accident were to occur, is estimated for most plants not to exceed the annual dose obtained from natural radioactivity.

Transportation

The nuclear fuel cycle requires the transportation of radioactive materials by truck or rail at several stages. Transportation of spent fuel elements from reactors to processing plants to storage sites poses potential hazards. Transportation regulations and cask designs have been developed to insure that transportation accidents will not release radioactivity to the environment.

Fuel reprocessing

Spent fuel assemblies from reactors are practically cooled and then transported to reprocessing plants where useable nuclear fuel materials are recovered and radioactive wastes are separated. In 1973 there were two operating fuel reprocessing plants, and one is under construction. Each reprocessing plant can serve 30 to 50 nuclear plants. Radioactive

emissions during fuel reprocessing are greater than those occurring during normal power generation, but the estimated maximum dose is two orders of magnitude below natural levels. Hence, the impact of emissions is not considered dangerous, even though the cumulative effects of such low level radioactivity are not yet fully evaluated.

Radioactive waste storage

High-level radioactive wastes remaining after reprocessing are concentrated and stored in solution for five years, then solidified, sealed in containers, and put into long-term storage. A nuclear plant with a capacity of 1,000 MW produces from 8,000 to 10,500 gallons of high-level waste per year and ultimately requires a storage capacity of 40,000 to 54,000 gallons. The liquid waste, when evaporated, yields 80 to 105 cubic feet per year of solid waste. These waste materials have a high concentration of radioactive nuclides with very slow rates of decay and must be isolated from the biosphere for hundreds to thousands of years if adverse effects to living organisms are to be totally avoided. Such waste is presently being stored in artificial underground facilities. Research is being conducted to find a permanent (several hundred years) storage repositor. As part of this research, pilot studies of storage in salt beds are being conducted.

Relationship of alternative to mining coal in the Eastern Powder River Coal Basin

The development of additional nuclear electrical generating capacity to replace the existing and planned coal-burning plants and

their fuel source, the Eastern Powder River Coal Basin of Wyoming, is a long-range alternative. Such additional nuclear capacity does not exist in the area served by these plants. The leadtime for the construction of such additional capacity from project inception to on-line generation approaches a decade and, therefore, is not an alternative to extracting federally-owned coal from the Eastern Powder River Coal Basin of Wyoming.

Geothermal Energy

The earth has a vast amount of internally generated and stored heat that is a potential energy resource. Power from this source probably will augment power from conventional sources increasingly in the future. Geothermal resources known to be easily exploitable for electric power in the U.S. at present occur in one area, the Geysers, California, where development of 1,000 MW of generating capacity is reasonably assured, and perhaps a total of 2,000-MW capacity may be developed ultimately. In 1973 operations at the Geysers had 298-MW generating capacity, or about 8.9 trillion Btu per year. In comparison, the projected Eastern Powder River Coal Basin production of 8 to 150 million tons per year will provide fuel for generating plants having a capacity far greater than the Geysers geothermal operation in 1973. Thus, geothermal power from the Geysers is not a viable alternative to the Powder River coal.

Geothermal energy is produced from wells in the form of steam. The heat energy in the steam must be used or converted to other forms of energy at the production site because heat lost from steam lines becomes substantial at distances greater than about one mile from the wellhead. Present geothermal steam-electric power plants are small (100-MW capacity or less), derive their energy from nearby steam wells, and are connected by high voltage transmission lines with other plants one to two miles away. Normally each plant is served by about 10 producing wells having a spacing of one well per 12 to 40 acres. At the Geysers, the Pacific Gas and Electric Company has settled on two 55-MW turbine generating units housed together as the optimum size for each plant in its grid (Barton 1971, pp. 23-27).

Because of technical and economic constraints, geothermal energy probably will not constitute a source of energy sufficient to meet the national

demand in the period 1974 to 1985. If energy sources can be found in favorable locations, geothermal energy may be important in several areas of the Western States; however, it probably will be insignificant as a factor in national power capacity (less than 1 percent of the total) through the year 2000 (U.S. Department of Interior 1972, p.57).

Land use patterns in the vicinity of geothermal developments would be changed by the construction of roads, wells, pipelines, powerlines, power plants, and support facilities needed for industrial development. Land having value for agriculture, forestry, grazing, fish and wildlife habitat, recreation, or water supply might be disturbed in varying degrees. The Geothermal Steam Act of 1970 considers these possibilities by excluding certain public and acquired lands from the geothermal leasing program to protect their special values or unique characteristics. In addition to restricting certain areas from geothermal leasing, Section 3200.0-6(b) of the leasing regulations requires that developments on adjacent lands, both public and private, must be evaluated prior to geothermal leasing to consider the impact of geothermal development.

Development of a large geothermal field could continue for many years as wells and power-generating units are added. Maintenance procedures, production testing, and presence of above-ground pipe systems present the most severe continuing impacts to the environment.

Most of the potential adverse environmental effects during the development phases of a geothermal field would be magnified during full-scale operation. The potential for environmental damage would increase with the addition of each new well. Some adverse environmental effects would be unavoidable, such as air and water pollution from accidental releases and noise incidental to

producing high-pressure steam. Others which could be modified would include destruction of wildlife habitat and restriction of surface use of land in the vicinity of the geothermal installation. Pipelines connecting as many as ten wells to a single power plant might form a network that could severely limit access to the steam field. The principal objection to geothermal power development stems from the intrusion of industrial development into new areas. Without planned mitigations, nearby residents and outdoorsmen generally would find the noise, odor, and disturbance of terrain and vistas objectionable.

Exploratory drilling and testing of geothermal steam resources could affect wildlife and fish. Most impacts would occur on or adjacent to well sites. The magnitude of particular impacts would depend on the size of development, the duration of development activities, and the effectiveness of control measures.

Blowouts, in which steam, water, and gases could escape uncontrolled, pose a potentially serious environmental hazard in geothermal drilling. Although seismic activity and subsidence increase the potential for blowouts, all failures of equipment to date have been caused by earth slides and improper design. The principal adverse environmental effects of accidental releases would be danger to operating personnel, noise nuisance, and contamination of the air and ground water by gaseous emissions such as hydrogen sulfide and ammonia. Blowouts might be difficult to control because of the risks in handling hot liquids and gases; however, unlike blowouts of oil or gas wells, geothermal accidents would be virtually free of fire hazard. To minimize blowout hazards, proper casing design would be required to assure that the pressurized fluid would be controlled at the wellhead by shut-off valves or other safety devices.

Where fresh-water aquifers occur above a geothermal reservoir that contains hot saline water, tapping a geothermal reservoir could result in contamination of the fresh water unless the aquifers were kept isolated from one another and from the reservoir by proper installation of well casing.

The ground surface over and around a geothermal field could subside during or after withdrawal of large volumes of fluid from the reservoir. Subsidence resulting from withdrawal of fluids (oil, gas, water from artesian aquifers) has been documented in many areas (Poland and Davis 1969). Subsidence could be prevented or checked by returning fluid to the reservoir.

One favorable environmental impact of electrical transmission lines would be improved fire protection resulting from clearing of the rights-of-way. The principal adverse impact would be aesthetic, due to the intrusion of powerlines and towers on vistas. Disturbance of the terrain would be minimal except for the clearing of trees and brush, although changes in vegetation cover caused by cutting of rights-of-way through forests could alter the feeding and migration habits of certain wildlife species, and erosion might be increased locally.

Geothermal waste fluids normally would be highly mineralized. Minerals causing the biggest problems would be silica, carbonate minerals, sulfate minerals, and salts of chloride and fluoride. Discharging mineralized fluids into streams and lakes would be generally unacceptable. Discharges to the ocean would likely be unacceptable if the local mineral and thermal loads increased as a result. Disposal to useable underground water likewise would generally be unacceptable. These problems could be solved in most areas by reinjection of waste fluids into the producing zone. This has the additional advantage of maintaining pressure in the geothermal reservoir. Alternatively, the wastes could be evaporated and minerals of economic value recovered.

Disposal of gaseous wastes would pose a problem. At some places, steam from cooling towers could produce fog. Certain objectionable gases, particularly hydrogen sulfide and ammonia, could be removed from power plant steam before release.

Hydroelectric Power

The potential hydroelectric capacity of the United States is limited. the capacity yet to be developed in the conterminous 48 states, approxi- tely one-third is likely to be developed by 1990 under existing programs. ıture hydroelectric sites probably will be developed in conjunction with ɔssil or synthetic fuel or nuclear base-load plants to supply supplemental ›ower for area load peaking requirements.

The generating potential of any hydroelectric site is a function of stream discharge and the height of fall. The better hydroelectric sites are concentrated in regions having heavy precipitation and large topographic relief. The following table shows the extent of U. S. potential and developed water-power capacity as of January 1971.

Table 16

U. S. Potential and Developed Hydroelectric Power Capacity
(In thousands of megawatts; statistics as of January 1971)

Geographic region	Potential power	Percent of total	Developed capacity	Percent developed
New England	4.8	2.7	1.5	31.3
Middle Atlantic	8.7	4.8	4.2	48.3
East North Central	2.5	1.4	0.9	36.0
West North Central	7.1	3.9	2.7	38.0
South Atlantic	14.8	8.2	5.3	35.8
East South Central	9.0	5.0	5.2	57.8
West South Central	5.2	2.9	1.9	36.5
Mountain	32.9	18.3	6.2	18.8
Pacific	62.2	34.6	23.9	38.4
Alaska	32.6	18.1	0.1	0.3
Hawaii	0.1	0.1	-	-
Total	179.9	100.0	51.9	28.8

Source: Federal Power Commission, National Power Survey Report, (December 1971) Part 1, 145 Chapter 9.

The potential hydroelectric capacity of the United States is 179,900 MW (megawatt) of which 28.8 percent or 51,900 MW have been developed, leaving approximately 130,000 MW to be developed. About 32,600 MW of undeveloped capacity is in Alaska. The economic feasibility of large hydroelectric projects in Alaska is doubtful because of the sparse population and remoteness from population centers. Of the approximately 100,000 MW of undeveloped capacity in the conterminous 48 states, 65,000 MW are concentrated in the Mountain and Pacific regions. About 35,000 MW of capacity could be developed in the remainder of the conterminous United States.

The Federal Power Commission (1971) estimates future electric generating capacity as follows:

Table 17

Estimated Future Electric Generating Capacity

Year	Total generating capacity, megawatts	Total hydroelectric capacity, megawatts	Hydroelectric, percent of total
1970	340,058	51,641	15.2
1980	665,000	68,000	10.2
1990	1,260,000	82,000	6.5

Source: Federal Power Commission, 1971. The 1970 National Power Survey, Part I.

Thus, it is estimated that by 1990 development of approximately one-half of the nation's total hydropower potential will comprise only 6.5 percent of total electric generating capacity.

Few dams are built solely for hydroelectric power generation. Irrigation, navigation, municipal and industrial needs for water, and flood control are the dominant considerations.

Potential environmental impacts

Hydroelectric power does not produce air pollution, radioactivity, waste heat, or water pollution, although the oxygen content of water in storage reservoirs might be lowered compared to the oxygen content of the intake streams. Impacts on land and water resources tend to be limited to the vicinity of the power generation site. Dams used for hydroelectric generating generally are used also for irrigation and flood control and the lakes commonly provide water and water-related recreational opportunities.

A hydroelectric dam represents an irretrievable commitment of the land resources beneath the dam and lake. Agricultural uses, minerals, wildlife habitat, river recreation, historical and archaeological resources, timber areas, and others are lost. Alteration of river gradients may lead to silting behind a dam, which progressively reduces reservoir capacity and its effective use and, finally, after many years results in filling the lake. Surges in downstream flow from power plant discharges can scour river banks and bottoms.

Wildlife and fish habitat may be adversely impacted. The reproductive habitats of anadromous fish may be severely altered by dam construction unless provision is made for fish ladders or other devices to provide safe passage for fish. Turbulent flow below dams increases mixing of air with water and augments the amount of nitrogen in the water, which may lead to nitrogen narcosis in fish.

Special problems - Alaskan hydroelectric power

A particular disadvantage of the Alaskan hydroelectric alternative would be the necessity of constructing transmission lines to carry surplus power from Alaska to the conterminous United States. The distance would range from 1,500 to 2,000 miles between the hydroelectric sites and the United States-Canadian border. Such distances preclude the use of alternating current transmission lines because of power losses, other technical problems, and the poor economics of transmitting alternating current long distances. Transmission of direct current assumes adequate technical developments by the time such lines would be required. Approximately 20 direct current lines rated at 1,000 kv (kilovolt) would be required to transmit approximately 30,000 MW from Alaska to the conterminous U. S.

Tar Sands

If technology can be developed to permit economic oil recovery from tar sand deposits, an estimated 17.7 to 27.6 billion barrels of oil from deposits in Utah could conceivably support an industry capable of producing as much as 500,000 barrels of oil per day for nearly 50 years. Deposits in Utah constitute the bulk of the known tar sand resource in the United States. Extraction techniques so far tested have been only marginally satisfactory, hence oil production from tar sands is not considered a likely energy source capable of serving as an alternative for the cola production from the Big Sky Mine.

Resource potential

Tar sands, also known as oil-impregnated rock, bituminous sandstone, and bituminous limestone, are distinguished from more conventional oil and gas deposits by the high viscosity of the contained hydrocarbons. These hydrocarbons are generally semi-solid to solid and not recoverable by ordinary oil well production methods. Initiating and sustaining production requires continuous addition of energy such as heat, fluid pressure, and mechanical work by mining.

Tar sand deposits in the United States are numerous and some individual deposits are widespread. The most intensive effort that has been made to evaluate the oil resource potential of tar sands in the United States resulted in the description of 546 occurrences in 22 states (U.S. Bureau of Mines, 1956). The lack of definitive information, however, resulted in only partial resource estimates for seven states. The estimated recoverable reserves in these states, in surface and near-surface petroleum-impregnated rocks, range between 2.5 and 5.5 billion barrels. Later refinements of data have been made in some

areas and indicate that the total oil in place in the known deposits ranges between 18.7 and 28.0 billion barrels. Most of the tar sand resource is in five large deposits estimated to be about 30 billion barrels.

The largest known tar sand deposit in the world is at Athabasca in Alberta, Canada. Estimates of the size of this deposit range from as little as 85 billion barrels of economically recoverable oil (Schurr and Homan 1971) to appreciably more than twice this amount. The National Petroleum Council (1971) estimated that 174 billion barrels may be economically recoverable.

A strip mining and extraction technology for the commercial production of oil has been developed to permit exploitation of the Athabasca tar sand deposit. Increased production from this deposit can be expected over the next few years as mining projects are approved and activated. The technology will have limited use for the tar sand deposits in the U. S. because none of the domestic deposits can compare in area, in volume of resource, or in thickness of overburden. The exploitation of U. S. tar sands will probably require in-situ methods for which the technology is now lacking. The time required to develop this technology and to develop a large tar-sand industry will probably prevent any appreciable oil production from U. S. tar sands until after 1985. Accordingly, production of oil from tar sands is not a currently available and viable alternative to coal from the Eastern Powder River Coal Basin.

Potential environmental impacts

The most severe environmental impact of tar sand extraction would result where the deposits are strip mined because of the immense tonnages

of overburden and oil-impregnated rock that would be moved and the large surface areas that would be disturbed. At Athabasca about 3.3 tons of tar sand and overburden are processed for each barrel of oil produced; the ratios are about 2.4 tons of sand and 0.9 ton of overburden per barrel of oil, depending on the bitumen content of the sand processed.

By comparison, in-situ recovery methods would not cause as severe disturbance of the surface as strip mining but would have other impacts on the environment. Regardless of the process used, the production of oil from tar sand deposits could produce hydrocarbons and other pollutants that would have to be removed from atmospheric emmissions to protect air quality. Air quality could also be affected by dust from the strip mining, from restoration activities, and from traffic on access and service roads during mining operations. Water supplies could be polluted from water draining from mine areas and from leaching of spoil in dump and disposal areas. Impacts on existing uses of the land would result, the principal effects being to reduce the area available for livestock grazing.

Strip-mined land would be unavailable for other uses until restoration. In-situ methods, which disturb comparatively little land area except around extraction and control wells and surface production facilities, would also affect land uses but to a lesser degree. Among the uses affected would be human habitation, recreation, livestock grazing, agriculture, and wildlife habitat, at least until oil production was completed and the facilities removed. Other impacts would include noise associated with the operation of process plants and equipment and population increases in areas of established plants due to increased labor requirements.

Oil shale

U.S. has abundant oil shale resourses that offer great potential to supplement conventional supplies of oil and gas. These resources have not been developed in the past because of availability of oil and gas from conventional sources at lower development costs. However, present and projected energy shortages have focused attention on the energy promised by oil shale.

Technological processes

The major options for oil shale development are: (1) mining followed by surface processing of the oil shale and shale-oil and (2) in-situ (or in place) processing.

Until recent years, virtually all efforts to develop oil shale technology were directed toward mining, crushing, and above-ground retortings. Oil shale processing in this manner would require the handling of large amounts of materials. In certain locations, the oil shale deposits contain minerals that may be amenable to recovery of additional by-products such as soda ash and alumina.

Oil shale mining can be conducted either at the surface or underground. The former, usually described as open-pit mining, involves removal and disposal of the surface material, or overburden, followed by mining the underlying oil shale in a quarry-like operation. The quantity of overburden significantly affects the development time and economics. Current open-pit techniques and existing large-scale equipment are expected to enable mine development at relatively low costs although disposal-restoration costs will be greater than similar costs for underground operations.

The room-and-pillar method has been extensively tested for underground mining of oil shale. In this development plan the recovery rate would depend

on the depth and local conditions. In general, about 60 percent of the shale can be removed. The remainder is left as pillars for mine support and to prevent surface subsidence. It is expected, however, that some mining operations would provide substantially lower total extraction percentages. Room-and-pillar mining is characterized by large rooms separated by the support pillars. The height of the rooms would depend on the thickness of the formation and the maximum height that would be practical for pillars. Access to the oil shale to be mined can be gained from the surface either by a vertical shaft or a horizontal adit or tunnel.

Crushing and conveying systems are technically and economically well established and are regarded as necessary parts of any integrated processing system. The selection of specific equipment is primarily based on the size of the oil shale fragments needed for subsequent processing.

Literally thousands of retorting processes have been patented worldwide for the production of oil from oil shale. Three processes that have been tested on oil shales of the Green River formation using large experimental equipment appear at this time to offer reasonable possibilities of technical and economic success if scaled up to commercial design size. These retorting methods include the gas-combustion process developed by the Bureau of Mines, the Oil Shale Corporation (TOSCO) process, and the Union Oil Company process. In each system heat is applied to raise the temperature of the oil shale to about 900 degrees F. at which point the solid organic material (kerogen) is converted to a liquid. The equipment, method of heat application, and operating procedures differ markedly for each system.

Oils from most retorting processes, with the possible exception of the TOSCO process, will require upgrading before the oil can be transported through pipelines to the final product refineries which are expected to be located

outside of the oil shale region. Modern refinery processes are suitable for subsequent upgrading. Each of the three retorts also produces a retort gas that may be used within the plant as a fuel or, alternatively, to generate supplemental electrical power for nearby communities.

Spent shale may be in the form of solid particles ranging from 10 inches in diameter to a fine powder, depending on the retorting method used. The spent shale is dry as it leaves the retort but it is moistened at the disposal pile in the process of recovering saline minerals. Disposal will depend on the physical characteristics of the material, its water content, and the location of the disposal area, whether surface or subsurface. The spent shale may be returned to the mine as a slurry.

Various processes for recovery of the saline minerals associated with the oil shales have been proposed.

The economical recovery of alumina, soda ash, and nahcolite (potentially valuable for removal of sulphur oxides from stack gases) from the deep oil shales has not yet been demonstrated on a large scale nor have the effects of their recovery been tested by current markets for these chemicals.

An alternate mining and processing technique, called in-situ processing, would involve the recovery of oil from the shale by heating underground, in place. Presently proposed heat sources for the in-situ recovery include underground combustion, hot natural gas, hot carbon dioxide, superheated steam, hot solvents, and combinations of two or more of these. It is anticipated that conduits for introducing heat underground would be provided by wells, mine shafts and tunnels, fractures created by a variety of techniques including nuclear explosives, or by a combination of these.

The essential steps of conventional in-situ based on contemporary petroleum technology are (1) well drilling, (2) fracturing to permit heat

transfer and movement of liquids and gases, (3) application of heat, and (4) recovery of products.

Technology of in-situ processing has not advanced as far as mining-aboveground technology. Experimental work has attempted to induce permeability in order to permit heat transfer and passage of gases and liquids, to control the process remotely with sufficient accuracy through wellbores from the surface, and, if nuclear explosives are used, to control possible ground motion and release of radioactivity.

Resource base

Oil shale deposits are found in many areas of the U.S. but many are low grade, small, and inaccessible. The richest deposits occur in the Green River formation in Colorado, Wyoming, and Utah in large topographic basins that are identified by streams draining most of the land surface. These include the Green River Basin and Washakie Basin in Wyoming, the Uinta Basin in Utah, and the Piceance Creek Basin in Colorado. Oil shale of possible commercial interest also occurs in Battlement and Grand Mesa in Colorado. These oil shales are found beneath 25,000 square miles (16 million acres) of land, of which about 17,000 square miles (11 million acres) are believed to contain oil shale with potential for commercial development. An estimated 73 percent of oil shale lands, containing nearly 80 percent of the Green River formation resources, are federally held.

The Green River formation contains known oil shales with about 600 billion barrels of equivalent oil in the higher grade deposits (averaging more than 25 gallons per ton and a minimum of 10 feet in thickness). Lower grade zones in the formation (averaging 15 to 25 gallons per ton) contain an additional 1,200 billion barrels.

About 80 percent of the known higher grade resources are found in Colorado, 15 percent in Utah, and 5 percent in Wyoming. This region is sparsely settled and arid or semiarid.

The following table shows another set of estimates of U.S. oil shale resources. The estimate of total identified resources for the Green River formation, 1.8 billion barrels, is the same as above, but the breakdown between high and lower grade resources differs. Of these 1.8 billion barrels, about 1.2 billion are found in the Piceance Creek Basin of Colorado and about 0.32 billion in the Uinta Basin. Of the high grade identified resources of 418 billion barrels, about 355 billion are found in the Piceance Creek Basin and 50 billion in the eastern part of the Uinta Basin.

Oil Shale Resources

Deposit	Identified* 25-100 gal/ton	Identified* 10-25 gal/ton	Hypothetical** 25-100 gal/ton	Hypothetical** 10-25 gal/ton
Green River Formation, Colorado Utah, Wyoming	418	1,400	50	600
Chattanooga Shale and equivalent formations, central and Eastern United States		200		800
Marine Shale, Alaska	small	small	250	200
Other Shale deposits		small	NE***	NE

*Identified resources refer to specific, identified mineral deposits that may or may not be evaluated as to extent and grade and whose contained minerals may or may not be profitably recovered with existing technology and economic conditions. This category is roughly equivalent to "average of 30 or more gallons per ton."

**Hypothetical resources refer to undiscovered mineral deposits, whether of recoverable, or subeconomic grade, that are geologically predictable as existing in known districts.

***Not estimated.

Source: U.S. Geological Survey.

The National Petroleum Council classifies resources based on commercial attractiveness:

Classes 1 and 2. The most accessible and better defined of the deposits at least 30 feet thick and averaging 30 gallons of oil per ton of shale. Class 1 averages 35 gallons per ton over a continuous interval of at least 30 feet.

Class 3. Deposits as rich as Classes 1 and 2 but more poorly defined and not as favorably located.

Class 4. Low grade, poorly defined deposits.

Oil Shale Resources of the Green River Formation

(Billion of Barrels)

Location	Class 1	Class 2	Class 3	Class 4	Total
Piceance Basin - Colorado	34	83	167	916	1,200
Uinta Basin - Colorado & Utah		12	15	294	321
Wyoming			4	256	260
Total	34	95	186	1,466	1,781

Source: National Petroleum Council.

Economic considerations

Projections of capital investment, prices of shale oil, and rate of development are dependent on each other and on assumptions concerning industry and government policies, technology, and required rates of return. The National Petroleum Council gives estimates of possible development under four set of conditions. Case I represents the maximum feasible production under nonemergency conditions and assumes shale oil prices adequate to encourage commercial development. Limitations on rate of development include availability of operating personnel, environmental restrictions, lack of supporting commerce and industry, and construction logistics. Cases II, III, and IV show slower rates of investment due to lack of investment incentive or need for time to demonstrate process feasibility.

Production of Shale Oil (MB/D)

	1975	1980	1985
Case I	0	150	750
Case II	0	100	400
Case IV	0	0	100

Source: National Petroleum Council

Price predictions are sensitive to the rate of return desired and the shale assay. "Price" developed by the National Petroleum Council is exclusive of transportation costs to refineries ($0.50 to $0.75 per barrel), leasing costs, or bonus payments. These prices are based on invested capital to build and equip two mines, two retort plants, and one upgrading plant to produce 100 MB/day of shale oil.

Required Shale Oil "Prices"
(Dollars per barrel)

Discount Cash Flow Rate of Return (%)	30 gallons/ton oil shale	35 gallons/ton oil shale
10	4.32 - 4.47	3.97 - 4.09
15	5.58 - 5.79	5.10 - 5.29
20	7.03 - 7.29	6.45 - 6.72

The detailed assumptions used in developing these projections are described in U.S. Energy Outlook. Prices will be influenced by royalty rates, depreciation and depletion allowables, and investment tax credit provisions.

On June 29, 1971, the Secretary of the Interior announced plans for a proposed prototype oil shale leasing program which would make available to

private enterprise, for development under lease, a limited amount of public oil shale resources. Such leases would be by competitive bonus bidding and would include assumption of certain royalty obligations to the United States.

The following excerpt from the final Environmental Statement for this program describes the rate of oil shale development that may be expected.

> For purposes of the present discussion, it is assumed that private lands would support no more than 400,000 barrels per day and that the six prototype tracts would support a total of 250,000 barrels per day. The combined output from private and public holdings would then reach 650,000 barrels daily by 1985. Additional public lands would be required to increase the production rate above this level. Even if suitable lands are available, the rate of development will be determined by the logistics of plant construction and by manpower constraints. Under these constraints, the Department of the Interior estimates the maximum 1985 production to be one million barrels per day. Even at this rate of production, only about 9 percent of the 80 billion barrels of prime commercial interest would be produced by the year 2000. The ultimate size of the oil shale industry will most likely not be determined by the magnitude of the oil shale resource base but will probably be limited by other factors such as the availability of water, for example.

Environmental impact

Land quality. The development of an oil shale industry would require roads, mines, plant sites, waste-disposal areas, utility and pipeline corridors, and associated services during the productive life of a lease. These activities

would change the existing pattern of land use, alter the existing topography, and affect natural vegetative cover until revegetative operations began. Such disturbances would unavoidably exist throughout the life of operations, but they would be temporary in the sense that restoration of surfaces to original or improved conditions would be required before site abandonment. The table following this page shows the amount of land that would be required for a 100,000 bbl./day surface mining operation, a 50,000 bbl./day underground mine operation, and a 50,000 bbl./day in-situ operation.

Processed shale could be returned to mined areas and deposited in canyons and gullies which would gradually be converted into flatter areas. Contouring and revegetation would restore scenic attractiveness and probably reduce erosion.

Where areas to be developed are now used for livestock grazing, agriculture, wildlife habitat, or recreation, some unavoidable loss in these patterns of land use would result.

Impacts would be significant in local areas but slight for the region as a whole because the percentage of the region's total surface area affected by development (including urbanization) would be small. However, the semi-remote character of the area would be modified and some local dislocations would unavoidably occur.

Water quality. One of the greatest possible impacts would be the requirement of large amounts of water for retort plants and the disposal of waste water. Approximately 150,000 acre-feet annually would be required for one million barrels per day of shale oil production.

In addition, as much as 10 gallons of water per ton of shale could be produced in the surface retorts. This water could contain dissolved saline and organic compounds. It could be used to moisten the waste shale to prevent dust

Land Requirements for Oil Shale Processing

Function	Land Required (Acres)
Mining and Waste Disposal:	
Surface Mine* ** (100,000 bbl./day):	
Mine development	30 to 85 per year
Permanent disposal, overburden	1,000 (total)
Temporary storage; low-grade shale	100 to 200 (total)
Permanent disposal; processed shale	140 to 150 per year
Surface facilities***	200 (total)
Off-site requirements+	180 to 600 (total)
Underground Mine** (50,000 bbl./day):	
Mine development (Surface facilities)	10 (total)
Permanent disposal:	
All processed shale on surface	70 to 75 per year
60 percent return of processed shale underground	28 to 30 per year
Surface facilities***	140 (total)
Off-site requirements	180 to 225 (total)
In-situ Processing (50,000 bbl./day):	
Surface Facilities***	50 (total)
Active Well Area and Restoration Area	110 to 900
Off-site Requirements	180 to 600 (total)

*Area required is dependent upon the thickness of the overburden and oil shale at the site. Acres shown are for a Piceance Creek Basin site, with 550 feet of overburden and 450 feet of 30 gallon/ton shale (approximately 900,000 bbl./acre).

**Assumes 30 gallons per ton oil shale and a disposal height of 250 feet.

***Facilities include shale crushing, storage and retorting (excluded for in-situ processing), oil ungrading and storage, and related parking, office, and shop facilities.

+Includes access roads, power and transmission facilities, water lines, natural gas and oil pipelines; actual requirements depend on site location. A 60-foot right-of-way for roads requires a surface area of about 8 acres per mile. Utility and pipeline corridors 20 feet in width require 2.4 acres per mile.

problems. However, it would require treatment prior to other uses to remove hydrocarbons, malodorous compounds, and, perhaps, dissolved minerals.

Large quantities of natural ground water occur in leached zones of the deep oil shale areas, but the location, composition, and movement of such waters have yet to be defined in many areas. These aquifers may contribute substantially to the overall water supply available to satisfy requirements for oil shale development. Other sources are the Colorado River and its tributaries in Colorado. In Utah potential sources for development of oil shale in the Uinta Basin are the Green, White and Yampa Rivers. In Wyoming the Green River is the principal surface water resource of the Green River Basin. To insure dependable supplies from these rivers might require construction of dams and reservoirs or purchase of water from existing reservoirs.

Use of ground water in oil shale development could decrease the natural discharge of springs and seeps. This could result in adverse effects on associated vegetation and any fish or wildlife dependent on that water supply.

Degradation of water quality could occur from discharge of product or waste waters, siltation of streams, or leaching of saline minerals from spent shale. It could be avoided in most cases by proper design, equipment, and adequate supervision and monitoring of operations. Leaching of spent shale would not be expected to be a problem because properly emplaced waste sites will harden through natural cementation.

In addition to these waters, there would possibly be a water slurry produced by a wet scrubbing process used to remove fine dust in gas streams. The slurry from the wet scrubbing could be used to wet the spent shale.

Water would also be used in the cooling phase of the process, but the amount needed could be kept to a minimum by employing air cooling. Any "sour"

water streams produced by accidental contact with oil in final water condensers would be treated by conventional oil refinery methods.

The nature of the foreseeable problems associated with water quality would depend largely upon the mineral characteristics of the processed shale and the method of disposal. The foreseeable problems, as outlined, are believed controllable with present technology.

Air quality. Proper techniques already exist to adequately control emissions, including particulates, sulfur oxides, and nitrogen oxides potentially present in various fuel gases and the dusts produced in mining and shale disposal. It is expected that all applicable federal and state criteria on acceptable air quality standards could be met. Residual concentrations of sulfur oxide, on the basis of a 200,000 bbl./day output, would total 12 to 40 tons per day depending on the process and nitrogen oxides would total 17 to 23 tons per day. Solid particulates in gaseous discharges to the atmosphere would be small but unavoidable at the present state of technology. New control techniques now being developed for other industrial operations could be incorporated into this industry. Some local problems with temperature inversion may be experienced, the significance of which cannot now be established. The long-term effect of industrialization would result in a decline in general air quality of the region.

The local noise level near developed sites is expected to increase due to mining, retorting, and other processing operations. This is an unavoidable adverse consequence of increased industrial activity in a region which is presently predominantly a semi-wilderness and can be only partially mitigated by noise abatement devices.

Impact on fish and wildlife. Construction and operation would have varying degrees of direct and indirect impacts upon fish and wildlife and their habitat in the immediate vicinity of the plants and along roads, surface facilities, and pipelines. Noise and associated human activities accompanying construction and operation would have a new effect of stress and disturbance on normal behavior and activity patterns of wildlife. Species which could be affected by such disturbances include mountain lions, bear, elk, mule deer, antelope, bob cats, sage grouse, blue grouse and migratory birds. Encroachment of humans causes loss of habitat, and often adjacent areas cannot support the displaced animals.

Air strips and increased air traffic would provide some source of aerial harassment of mule deer, wild horses, and big game, the extent of which would be dependent upon the number and location of air strips and the volume of air traffic which would be involved.

Wildlife food and cover values of lands used for mining, pipeline and road construction, building, etc., would be at least temporarily lost. Permanence of such losses would be dependent upon the time required for and success of reestablishing useful wildlife food and cover. Such habitat loss would in turn result in lower populations of animals. For example, removal of critical winter browse would result in a corresponding reduction in mule deer numbers.

Oil shale-related drying of surface water features, such as springs, seeps, and small streams, would change the natural plant-animal complex associated with each particular water feature, including the related distribution of game, wild horses and cattle.

Coverage of roadside vegetation with vehicle-caused dust would constitute a minor but chronic problem since such vegetation would lose its wildlife food value until washed off by subsequent rains.

Unpredicted or uncontrollable changes in the quality of local surface or ground water would result in accompanying impacts on aquatic fish and wildlife populations and their habitat. In the event that sediment, leached substances, saline ground waters, and/or toxic materials were released to surface waters as a result of oil shale operations, adverse impacts would be imparted to aquatic plant and animals. Unless carefully controlled, such discharges would have adverse effects on aquatic habitat of the Colorado, Green, and White Rivers and other exposed water areas. Adverse impacts would also be expected in exposed aquatic habitat in the form of lowered biological productivity, physical covering of fish spawning, and nursery areas.

Handling, storage and transmission, including feeder pipelines, would exhibit some small losses of oil. Spills would follow natural drainage features and released oil would kill trees, shrubs, and other vegetation with which it came into contact. Birds, some species of both land and water mammals, and fish and other aquatic organisms would be adversely affected if they came in contact with the oil.

Oil shale-related urbanization would also create stress on regional wildlife populations. Reductions in surface water quality near population centers as a result of sewage, toxic substances and siltation would adversely affect aquatic organisms and their habitat. Some wildlife habitat would be consumed by buildings, roads, parking lots, etc. Additional wind and water erosion would occur. Increased ground vehicle traffic would result in more frequent road kills of deer and other game.

Increased hunting pressure would cause localized adverse impacts upon wildlife through reduction of populations of some species, including a few already scarce species such as the brown bear and cougar. Increased harvest of mule deer, elk, moose and antelope would require regulation in order to avoid

undesirable downward population trends. Both development and associated urbanization would aggravate conditions which cause some species to be classified as rare and endangered. Semi-remote hunting and fishing qualities would be lost.

Increased economic growth resulting from oil shale development would significantly alter existing social structures and institutions. The evolution of an agricultural society to an industrialized one would be largely irreversible and might produce intermediate community instability. Existing life styles with their emphasis on recreational activities and subsistance economic patterns eventually would be replaced by an urbanized way of life.

Relationship of alternative to proposed continued coal mining in the Eastern Powder River Coal Basin of Wyoming

The oil shale industry in the U.S. is in the earliest stages of development and is clearly not a viable alternative to the immediate needs of the existing coal-burning electrical generating station presently being supplied nor those planned to use coal from the Eastern Powder River Coal Basin of Wyoming.

Energy Conservation

The United States has the highest per capita consumption of energy and the highest per capita income in the world. Energy has provided the foundation for a continued rise in our material standard of living. Demand for energy in the U. S. has increased at an average rate of 3.1 percent annually for the last 20 years, more than twice the growth rate of the U.S. population. Higher energy use per capita compounded by population growth has produced unprecedented levels of energy consumption. As population growth slows, increasing per capita demand will account for a larger and larger share of the increasing total demand for energy. These trends are illustrated in Table 18.

Table 18

U. S. Total and Per Capita Net and Gross Energy Inputs

Year	Gross energy input, quadrillion Btu	Net energy input, quadrillion Btu	Population millions	Gross energy input per capita, million Btu	Net energy input per capita million Btu
1950	34.0	29.7	152.3	223.2	194.8
1955	39.7	34.3	165.9	239.3	206.7
1960	44.6	38.2	180.7	246.8	211.5
1965	53.3	45.3	194.2	274.4	232.1
1970	67.4	56.0	204.8	329.1	273.6
1975	80.3	65.1	216.2	371.4	301.2
1980	96.0	76.1	229.4	418.5	330.8
1985	116.6	89.7	243.3	479.2	369.9
2000	191.9	140.1	279.7	686.1	500.9

Source: U. S. Department of the Interior United States Energy Through the Year 2000, by W. G. Deupree and J. A. West (1972).

In the past, energy growth has been little constrained by price or by supply of resources. However, recognition that environmental costs should be reflected in price of energy, concern over environmental quality, and uncertainty of both immediate and long-term energy supplies have added urgency to the study and realization of the importance of energy conservation.

Energy demand growth can be reduced by slowing population growth and reducing per capita energy use. Potential reductions in population growth are limited as reproduction appears to be approaching replacement level. The more important factor in growth of energy demand has not been population growth but higher energy use per capita. In a study of electricity demand, alternative

population projections showed that "the population assumption is unimportant for demand growth in the next 20 to 30 years" (Chapman, Tyrrel, and Mount 1972).

The most promising approach to reduction in demand is through lower per capita use of energy. The rate of growth of per capita energy demand could be reduced by (1) reducing the rate of growth of demand for the goods and services produced with energy, (2) producing the demanded goods and services more efficiently, and (3) converting energy to useful work more efficiently.

A study on energy conservation focuses particularly on short-term and mid-term user conservation measures (Office of Emergency Preparedness 1972). The measures suggested could reduce energy consumption by 5.0 quadrillion Btu (QBtu) a year in 1975, 15.5 QBtu a year in 1980, and 33.4 QBtu a year after 1980. These energy savings represent the maximum that could be achieved if all the suggested measures were implemented. Because many of the suggestions depend on voluntary cooperation, the estimates must be regarded as the upper limit of savings.

The Office of Emergency Preparedness (OEP) found the greatest potential for energy conservation in (1) improved insulation in homes, (2) adoption of more efficient air-conditioning systems, (3) shifting of intercity freight from highway to rail, intercity passengers from air to ground travel, urban passengers from automobiles to mass transit, and freight consolidation in urban freight movement, and (4) introduction of more efficient industrial processes and equipment.

The following outline of specific measures directed at the four major consuming sectors--transportation, residential/commercial, industry, and utilities--is quoted from the study. These measures could be implemented through standards and regulations, tax incentives, and educational campaigns.

Short-term measures (1972-1975)

Transportation

Conduct educational programs to stimulate public awareness of energy conservation in the transportation sector; establish government energy efficiency standards; improve airplane load factors; promote development of small engines/vehicles; improve traffic flow; improve mass transit and intercity rail and air transport; promote automobile energy-efficiency through low loss tires and engine tuning.

Savings - 1.9 QBtu/yr. (10 percent)

Residential/commercial

Provide tax incentives and insured loans to encourage improved insulation in homes, encourage use of more efficient appliances and adoption of good conservation practices.

Savings - 0.2 QBtu/yr. (1 percent)

Industry

Increase energy price to encourage improvement of processes and replacement of inefficient equipment; provide tax incentives to encourage recycling and reusing of component materials.

Savings - 1.9-3.5 QBtu/yr. (6-11 percent)

Electric Utilities

Smooth out daily demand cycle by means of government regulation; facilitate new construction, decrease electricity demand.

Savings - 1.0 QBtu/yr. (4 percent)

Mid-term measures (1976-1980)

Transportation

Improve freight handling systems; support pilot implementation of most promising alternatives to internal combustion engine; set tax on size and power of autos; support improved truck engines; require energy-efficient operating procedures for airplanes; provide subsidies and matching grants for mass transit; ban autos within the inner city; provide subsidies for intercity rail networks; decrease transportation demand through urban refurbishing projects and long range urban/suburban planning.

Savings - 4.8 QBtu/yr. (21 percent)

Residential/commercial

Establish upgraded construction standards and tax incentives and regulations to promote design and construction of energy-efficient dwellings including the use of the "total energy concept" for multi-family dwellings; provide tax incentives, R&D funds and regulations to promote energy efficient appliances, central air conditioning, water heaters and lighting.

Savings - 5.1 QBtu/yr. (14 percent)

Industry

Establish energy use tax to provide incentive to upgrade processes and replace inefficient equipment; promote research for more efficient technologies; provide tax incentives to encourage recycling and reusing component materials.

Savings 4.5 - 6.4 QBtu/yr. (12-17 percent)

Electric utilities

Restructure rates for heavy uses to smooth out demand cycle; facilitate new construction.

Savings - 1.1 QBtu/yr. (4 percent)

Long-term measures (beyond 1980)

Transportation

Provide R&D support for hybrid engines, nonpetroleum engines, advanced traffic control systems, dual mode personal rapid transit, high speed transit, new freight systems, and people movers; decrease demand through rationing and financial support for urban development and reconstruction.

Savings - 8 QBtu/yr. (25 percent)

Residential/commercial

Provide tax incentives and regulations to encourage demolition of old buildings and construction of energy-efficient new buildings; R&D funding to develop new energy sources (solar, wind power).

Savings - 15 QBtu/yr. (30 percent)

Industry

Establish energy use tax to provide incentive for ungrading processes and replacing inefficient equipment; promote research in efficient technologies; provide tax incentives to encourage recycling and reusing component materials.

Savings - 9-12 QBtu/yr. (15-20 percent)

Electric utilities

Smooth out daily demand cycle through government regulation; facilitate new construction; support R&D efforts.

Savings - 1.4 QBtu/yr. (3 percent)

The OEP estimates that by 1980 space heating and cooling requirements could be reduced by 20 percent through improved insulation and a nationwide education program to encourage conservation practices in the home. Thermal insulation reduces the energy required for air conditioning, an important factor in summer peak loads of utility systems. Different models of air conditioners vary greatly in efficiency. The least efficient consumes 2.6 times as much electricity as the most efficient to provide the same cooling. If more efficient air conditioners were used, the annual power consumption for air conditioning in 1970 could have been reduced about 40 percent. The connected load would have also been decreased by 40 percent, or by 17,800 MW (Hurst and Moyers 1972).

A revision of the Federal Housing Authority's Minimum Property Standards (MPS) for single-family dwelling in 1971 established thermal design criteria for qualification of residences for FHA-insured mortgages. However, new homes constructed through conventional financing are not required to follow these standards. The revised FHA-MPS do not distinguish between electrically heated and combustion heated homes. A study of construction practices found that appreciable energy savings and some monetary savings to homeowners were possible through stricter insulation requirements. Wider application of these standards and additional insulation beyond the MPS requirements would afford further energy savings.

Substantial reductions are also possible in the transportation sector. The transportation of people and goods comprised 24.5 percent of U. S. energy consumption in 1970. Increases in transportation energy consumption are due primarily to growth in levels of traffic and shifts to less efficient energy modes. Table 19 shows energy requirements for transport of freight and passengers. The efficiencies are typical of the mid-1960's.

Table 19

Energy Requirements for Transportation Modes

Freight transport	Efficiency of freight, Btu/per ton mile	Passenger transport	Efficiency of passenger, Btu/per passenger-mile
Pipeline	450	Bicycle	200
Waterway	540	Walking	300
Railroad	680	Buses	1,200
Truck	2,300	Railroads	1,700
Airplane	37,000	Automobile	4,500
		Airplane	9,700

Source: Oak Ridge National Laboratory 1971 Energy Consumption for Transportation in the United States, by Eric Hurst

The shift from railroads to truck and airplane in freight traffic and from railroads and buses to airplanes has caused declining energy efficiency. The trend is encouraged by preferential government policies favoring air and highway transport. Low average car occupancy, use of cars for short trips, and disregard for congestion problems increase fuel consumption and pollution.

Hurst and Moyers compared two transportation models, an actual and a hypothetical case, to illustrate possible savings through use of energy-efficient transport modes (Hurst and Moyers 1972). Comparison of the two cases revealed that adoption of the hypothetical case would require 71 percent as much energy as the actual 1970 case. Assumptions underlying the hypothetical case include the following:

1) Half the freight traffic carried by conventional methods (truck and air) is to be carried by rail.
2) Half the intercity passenger traffic carried by air and one-third the traffic transported by car are to be carried by bus and train.
3) All the urban automobile traffic is to be carried by bus.

Socio-economic factors that might inhibit shifts to the energy-efficient transport modes are ignored in the analysis. Such factors include existing land-use patterns, capital costs, changes in energy efficiency within a given mode, substitution among modes, new technologies, transportation ownership patterns, and other institutional variables.

A comparison between the actual and hypothetical cases identifies the principal components of energy-use patterns and emerging considerations that may precipitate the shift toward increased energy efficiency in urban transportation. Variables influencing the current energy mix include personal preferences, private economics, convenience, speed, reliability, and government policy. Current transportation patterns are altered by factors such as fuel scarcities, rising energy prices, dependence on foreign petroleum, urban land-use problems, and environmental considerations.

The OEP study suggested that short-term measures could produce a maximum energy savings in the transportation sector of 1.9 quadrillion Btu per year by 1975, equal to 10 percent of transportation demand. Such measures would include educational programs, establishment of government efficiency standards, improved airplane load factors, smaller engines and vehicles, improved mass transit, and improved traffic flow. Public awareness of energy conservation and alternatives would foster a clearer understanding of the energy implications of decisions. A change in public attitudes toward walking, bicycling, and mass transit might do much to reduce demand for energy. Reductions in fuel consumption accomplished by voluntary measures during the oil crisis in late 1973 demonstrate changes in public attitudes.

Another sector of great potential for energy conservation cited by the OEP study is industry. OEP projects that, with the exception of the primary metals sector, industrial demand for energy under existing technology could be reduced by 5 to 10 percent with sufficient economic incentives (possibly price increases or an energy tax). Often less efficient equipment is chosen because capital expenditure is recovered in a shorter time. Incentives for selection of more efficient equipment could counter higher capital expenditures. Industrial energy demand can also be cut by recycling metals. For nonferrous metals, the amount of energy required to recycle scrap metal is less than 20 percent of that required to refine the metal originally, although new low-energy primary metal extraction methods are in development.

The imbalance between supply and demand for energy can be narrowed through the price mechanism. In the past, use of air, water, and land resources has been virtually free. If a price were put on social costs reflecting

depletion of resources and damage to the environment, energy patterns would tend to shift in order to reduce demand and conserve natural resources. For example, an electric rate schedule including higher charges for peak period usage would encourage consumers to shift use to other times of day, resulting in more efficient use of existing plants and less construction of new generating capacity to service peak demand. Tax credits and penalties could encourage development of cleaner and more efficient technology. For example, an auto tax would make it more expensive to drive a car and encourage use of mass transit.

Response of energy demand to increases in prices of energy is difficult to predict. In the short-term, gradually rising prices may have negligible effects. The study cited previously in the discussion of population growth concluded that substantial cost increases and reduction in population growth will noticeably lower electricity demand growth in the 1980's and 1990's. Given the lengthy time period of response, growth reduction in the 1970's might be limited. The authors give the following preliminary estimates of elasticity of electricity demand for electricity prices, income, population, and gas prices (Table 20).

Table 20

Summary of Electricity Demand Estimated Elasticities
for Electricity Prices, Income, Population and Gas Prices

Factor	Consumer Class Residential	Commerical	Industrial
Average electricity price	-1.3	-1.5	-1.7
Population	+ .9	+1.0	+1.1
Income	+ .3	+ .9	+ .5
Average gas price	+ .15	+ .15	+ .15
Percent of response in first year	10	11	11
Years for 50 percent of total response	8	7	7

Source: Chapman, Duane, Tyrrel, Timothy, and Mount, Timothy, Electricity Demand Growth-Implications for Research and Development, (June 1972).

The elasticities of demand represent the relationship of the percentage change in electricity demand and the percentage change in the factor. For example, the commercial elasticity for electricity prices of -1.5 means that a 20 percent rise in average commercial electricity price would in the long run cause demand to be 30 percent less than it otherwise would have been.

The kind of public policies that would be required to reduce demand, according to Michael McCloskey, Executive Director of the Sierra Club, would include the replacement of the market system to determine how much energy shall be produced or imported and who shall consume energy, with a detailed control on the production, importation, and use of energy in all sectors and regions of the economy. In his evaluations relative to controlling energy growth, McCloskey (1971, pp. 587-605) states:

> "A short-run strategy would involve the following changes in public policy: ending or reducing the many biases in public policies which provide incentives to energy growth; maintaining and strengthening environmental constraints on energy growth; reducing energy demands by educating the public to understand the importance of conservative use of energy: encouraging intensified research and development in order to achieve greater efficiencies in energy utilization and in order to find new, more environmentally acceptable energy sources and discouraging growth in industries that are the most profligate consumers of energy. Coordination of these efforts would be facilitated through the establishment of new government agencies, specifically geared to respond to the energy problem. Each of these changes would involve efforts that would go well beyond the traditional bounds of energy policy, and all could have profound economic and social impacts. Yet changes are already beginning to occur in all these fields, and environmentalists are determined to promote them."

To coordinate energy programs and carry out the directives of President Nixon's April 18, 1973, Energy Message, Secretary Morton of the Department of the Interior created the Office of Energy Conservation, the Office of Energy Data and Analysis, and the Office of Research and Development. The Office of Energy Conservation will promote consumer awareness of energy conservation, develop studies on measures to reduce energy requirements, coordinate all federal agency programs relating to energy conservation, and work to obtain federal, state, local, and industry participation in energy-saving programs. In December 1973, the Federal Energy Administration was created to centralize all policy planning and to manage federal fuel allocation, conservation, and perhaps rationing. This super-agency incorporated units of the Department of the Interior, Cost of Living Council, and the Office of Management and Budget.

Development of untapped energy sources and more efficient methods of energy conversion offer long-range possibilities for conservation of scarce nonrenewable resources. Long-term sources such as geothermal steam, tar sands, hydrogen and solar energy, and conversion techniques such as the fuel cell and magnetohydrodynamics are discussed elsewhere in this chapter.

The environmental benefits of energy conservation depend on the energy mix that evolves. Reduced consumption of energy from one or several sources may be balanced by increased consumption of energy from other sources. Environmental impacts of each individual energy alternative are discussed in the section on that alternative.

Other Energy Sources

Other energy sources that might in the future be alternatives to coal are not presently considered viable alternatives because production technology is not developed, and time for development would be measured in several years or tens of years. These include improved fuel-use efficiency, tidal power, solar energy, biological conversion of wastes to oil, and the use of liquid hydrogen as a fuel.

The potential environmental impacts of these alternatives are difficult to assess, particularly when research and development must be done before operational-scale systems can be developed, tested, evaluated and readied for production. No appreciable energy can be obtained from these systems within a relevant time frame. The following sections briefly describe the current and short-range status of each of these potential alternatives.

Magnetohydrodynamics

Magnetohydrodynamics (MHD) power generation is a technique for generating electricity in which a hot ionized gas or liquid metal is passed through a magnetic field. High-temperature one-stage conversion to electricity utilizing this technique has the potential of high overall efficiency. The concept of MHD generation has been known for more than 100 years, but only during the past decade have technological advances produced systems that offer promise for use in generating electric power. Three approaches to MHD power generation are being explored -- open-cycle, closed-cycle and liquid metal systems.

MHD open-cycle generation, used as a "topping unit" in conjunction with steam-turbine generation, appears to hold the most promise for MHD central-station power generation in the near future. As technology develops, overall system efficiency is expected to be in the range of 50 to 60 percent, which would provide a fuel saving of 20 to 30 percent compared to conventional fossil fuel steam-electric plants of the same capacity. Widespread use of coal-fired MHD topping units by the mid-1980's would extend fossil fuel reserves and enhance the use of coal for power generation. MHD generators require little cooling water and combined MHD-steam units would require considerably less cooling water per megawatt of capacity than conventional fossil fuel or nuclear steam-electric units. Before MHD can be used in central power stations, several difficult technological problems must be solved. Economically practical systems have not been demonstrated for burning coal or coal-derived fuels in MHD generators. Present designs are for small-scale devices having short lifetimes and lower efficiencies than would be required for utility operation. Problems remain in developing high-temperature electrodes, super-conductivity magnets, seed-recovery systems, and high-temperature erosion- and corrosion-resistant metals.

The characteristically high temperature and gas-passage time in MHD power generating devices tend to fix nitrogen; hence appreciable air-quality problems may arise from emissions of nitrogen oxides.

MHD research presently is being conducted in the United Kingdom, France, Germany, Japan, Poland, the Soviet Union, and the United States. The Soviet Union appears to have made a strong commitment to the development of MHD for commercial use. Soviet engineers express confidence that an open-cycle MHD unit of appreciable power output will be operating in the 1970's

but there is as yet no evidence of proven economic feasibility. A 75-MW combination MHD-steam pilot plant (25-MW MHD and 50-MW steam) is being constructed near Moscow. For the present, only the one 25-MW MHD unit is planned for completion and operation. Japan appears to have made great strides in achieving the high-field super-conductivity magnets necessary for MHD.

Utility companies, manufacturers, research institutions, and the U. S. Government have been actively involved in MHD investigations since the 1950's. Research and development are needed in many problem areas before MHD power systems can proceed to full-scale prototype.

Some advantages and disadvantages of MHD power generation compared to conventional coal-fired steam systems, per unit of electrical energy produced, can be summarized as follows:

Advantages	Disadvantages
Fuel savings of as much as 30 percent	Possible increase in No_x emissions
Saving in use of water	
Reduction in thermal pollution of water	
Reduction in coal mining and attendant environmental hazards	
Possible lower total volume of noxious emissions discharged to the atmosphere	

Fuel cells

Fuel cells are devices in which chemical energy is converted continuously and directly to low-voltage direct-current electricity. The

process is similar to that of a battery except that the fuel cell is an open system requiring a continuous supply of reactants for the production of electricity. Advantages over more conventional energy conversion systems are quietness, low temperature of operation, low level of pollution, reliability, and greater efficiencies (as much as 70 percent). A ton of coal in a suitable fuel cell system would yield nearly 50 percent more electrical energy than if burned in a conventional power plant.

Considerable research and development of fuel cells has been done in the United States and Europe. Most research in the United States has been directed towards specialized space and military applications, but work has also been done on power production for industrial applications. Near-term uses of fuel cells will be for storage cells that can be recharged during periods of off-peak power demand for local reserve or emergency power; cells for specific uses in homes, factories, or commercial establishments; and cells to provide power for vehicles.

Because fuel cells presently require costly metal catalysts and costly reforming and fuel purification, their potential uses in a mass market, even for small power units, is remote. They will come into general use only when efficient, reliable, and long-lasting units are developed capable of using impure, low-cost fuels. Even then the fuel cell is not expected to replace more conventional power generation from central stations.

Thermoelectric

When two dissimilar metals are joined in a loop and one of the junctions is heated, an electric current flows in the loop. This thermoelectric

phenomenon will doubtless receive continued attention for special low-power application such as for control devices. Short operating lifetime, high temperatures, and undesirable heat transfer from the hot to cold junctions, which results in low efficiencies, will be major obstacles to producing large quantities of electricity in applications such as generating electricity for central power stations.

Thermionic generation

When a metal is heated sufficiently, its electrons acquire enough energy to overcome retarding forces at the surface of the metal and escape or "boil off." If the electrons are collected on another, cooler metal surface, electrical energy can be generated by joining the two pieces of metal with an external circuit. Thermionic generators, and devices such as these are called, are a type of heat engine, and their efficiency theoretically is limited to 35 to 40 percent. Test models have efficiencies that range from 5 to 25 percent. Commercial thermionic generation awaits development of materials that will withstand temperatures above 3,000°F and that will withstand radiation damage in devices fueled with radioactive materials. Thermionic development during the next decade will be concentrated in space-oriented activities, principally nuclear-fueled systems for interplanetary expeditions (Federal Power Commission 1970). Large-scale industrial thermionic generation is not likely within the next several decades. Hence, such conversion systems do not represent an alternate energy source to coal in the near future.

Tidal energy

Tidal power is a potential hydroelectric energy source. The energy is derived from the alternate filling and emptying of a bay or estuary. Two places in the United States have potential for development (Bernshtein 1965). The Bay of Fundy, Maine, has nine possible sites for dams and generators including sites on the Canadian side of the bay. The potential power capacity of these sites is approximately 20,000 MW, Turnagain Bay in Cook Inlet, Alaska, has an estimated potential power capacity of 9,500 MW. The distance from population centers makes development of Turnagain Bay doubtful. If the Bay of Fundy capacity were developed, and half of the production went to Canada and half to the United States, the total addition to U. S. capacity would be about 15,000 MW, or about 1.1 percent of the power needs projected for 1990.

Channeling the flow of water to and from bay and estuarine areas could have adverse impacts on sport and commercial fisheries, recreation and aesthetic values.

The major technological problem in converting tidal energy to electricity would be the need to develop turbines able to operate economically under low hydrostatic heads (U. S. Department of the Interior 1972c). The overall impact of tidal power on the U.S. energy supply would be minimal and it does not represent a significant alternative to coal.

Wind energy

Wind energy has been used for many years for local domestic uses such as driving pumps or electric generators where other forms of energy are unavailable. Wind forces vary unpredictably at many locations, thus requiring large energy storage facilities for any sustained use of wind energy

for power. It has been estimated that the ultimate energy potential of wind in the U. S. at elevations within reach of aerogenerators located on towers is 20 billion kw.

Wind is pollution free and, therefore, attractive as a source of electrical energy. The primary adverse environmental effect would be the damage to aesthetic values. Towers used to support wind turbines would detract from scenic views and if concentrated in favorable areas would impede free access.

Wind energy does not appear to be a viable alternative to traditional energy sources. Even with reasonable progress in equipment design, favorable cost-benefit ratios are questionable because of the high equipment costs for many small units and the unreliability of the power source.

Solar energy

The sun is a source of both heat and electromagnetic radiation. Although the solar energy flux density is low (about 430 Btu per square foot per hour), the United States land area intercepts each year about 600 times its total 1970 energy requirements. Shortwave radiation from the sun can be used directly or converted by photochemical reactions into energy useable for applications such as electricity generation, space heating, cooling, and processing of industrial materials. Solar house heating, production of domestic hot water, solar distillation to produce fresh water from saline water, evaporation to concentrate brines, and production of electric power from photovoltaic cells for special use such as space research are some present day applications that may come into more widespread use in the future.

Not only is solar energy extremely dilute but energy collection and conversion efficiencies are low. Solar energy fluctuates diurnally and seasonally so that for most applications, energy storage facilities are an important requirement.

A typical 1,000 MW power plant operating in a 1,400 Btu per day solar climate would, with present technology, require 37 square miles of collector surface (assuming efficiency of conversion of solar energy to heat is 30 percent and to electrical energy is 5 percent.) The many square miles of collector surface required for even a medium-sized power facility would have an appreciable impact on land use. There would be a major aesthetic intrusion in desert areas which now are generally undisturbed by man's activities.

The requirement for large collector areas and the low efficiencies make it unlikely that solar energy will become an important source of power within this century. Even a 300 percent increase in solar cell efficiency would not result in economically acceptable power costs for general use. A massive research and development effort over an extended period of time would be required to reduce costs, increase conversion efficiency, and achieve acceptable system performance.

Another scheme for converting solar energy to electricity would exploit solar-produced temperature differentials between the upper and lower levels of the sea in the Caribbean region and in the Gulf stream. Orbiting space vehicles might also be used as solar collecting stations. Systems such as these have not yet been developed or tested and thus do not represent feasible energy source alternatives.

Use of solar energy for heating and cooling of buildings (both residential and commercial) in many areas of the nation appears much more feasible than generation of electric power. Although not a power source per se, this use of solar energy would substantially reduce power requirements for heating and air conditioning. Solar heating and cooling is receiving a great deal of interest and study at this time and may eventually be a suitable substitute for much of today's power demand. At the present time, however, solar heating and cooling systems are in the research and development stage.

Recycling organic wastes

Organic wastes in the United States are potentially a source of appreciable energy. The annual production exceeds 2 billion tons and includes about 880 million tons of organic moisture-and-ash-free material. Animal manure is the largest single source of organic waste; however, other agricultural wastes, urban refuse, and commercial waste are important contributors. Organic wastes that can be converted to low-sulfur oil have a potential yield of 1.25 barrels of oil per ton of waste (U.S. Bureau of Mines 1971c). If all the organic wastes produced in the U.S. were converted to oil, more than 1.3 billion barrels of oil per year would be produced. This amount is about 25 percent of the 1970 U.S. petroleum demand of 5.4 billion barrels. One half of the organic wastes would supply the current volume of fuel oil now used for electrical generation. It seems likely, however, that only a small fraction of the organic wastes could be collected at reasonable cost.

Preliminary research on the conversion of organic wastes to oil has been done in closed batch autoclaves. Currently, a continuous unit with

a capacity of 20 pounds of waste per hour is being operated. Additional work will be required for several years to prove technological feasibility, develop adequate economic data, and construct commercial facilities.

Recycling of organic wastes would alleviate many critical solid waste-disposal problems confronting the nation. Water-quality problems near livestock feedlots and disposal of agricultural wastes could be mitigated. The acreage needed for landfills could be greatly reduced because the solid residue from the conversion process would consist only of the mineral constituents in the original charge. The quantity of these constituents would be small, sterile, and easily disposed of in landfills. Because the process produces a low-sulfur oil with high heat value, it could reduce the need for natural oil production.

It is doubtful if commercial installations can be achieved by 1985. Because of the need for further research and development, this alternative cannot be considered viable at this time.

Liquid hydrogen

The use of liquid hydrogen as an alternative to fossil fuel for vehicular power systems appears to be technically feasible. Hydrogen would be separated from oxygen in water by an electrolytic process at a central power station. The hydrogen then would be liquified, transported, and distributed as fuel.

Prior to 1958, liquid hydrogen was produced only in small quantities and was primarily a laboratory curiosity. In response to demands made by the space program, facilities were constructed in the United States to produce more than 150 tons per day, but costs are relatively high. Cost

projections for the electrolytic production of hydrogen range from a low of \$0.04 per pound using electrical energy from a large breeder-type reactor to about \$0.12 per pound using other energy sources for electrolysis. By comparison, the present cost to produce gasoline is about \$0.02 per pound.

Because of the high conversion costs and lack of large-scale conversion facilities, this alternative is not viable. Use of hydrogen as a vehicle power source has the advantage of being pollution free because the combustion product is water. Conventional energy sources would be used in the conversion process; therefore, pollution from those sources would have to be abated at the point of manufacture.

Combinations of Alternatives

In the interest of clarity, this statement has discussed separately each potential alternative form of energy as a possible substitute to the mining of the federally owned coal in the Eastern Powder River Coal Basin of Wyoming. Power plants supplied by Powder River coal are coal-burning and no other alternative type of fuel can be substituted. In addition, coal from the basin plays an important role in the energy spectrum of a good portion of the United States already in short supply for oil and gas. If the mining of federally owned coal from the basin is prevented, an equivalent amount of fuel must be supplied almost immediately from other sources, if the power plants now using the coal are to stay in operation. Probably a combination of some of the alternatives discussed in this statement could provide the energy required in the long term, either by conversion of currently dependent plants or by other plants designed and built to use the kind of fuel that would be supplied. Understanding the extent to which the alternatives may individually or collectively replace or complement the coal mined from the basin requires a knowledge of the characteristics of our total national energy system. The factors that are most relevant are outlined below:

1) Energy requirements historically increase at about the same growth rate as gross national product.

2) Energy requirements can be reduced and constrained to some degree through the price mechanism in a free market or by more direct constraints. A direct constraint that can reduce energy requirements is substitution of capital

investment for energy; for instance, insulation to save fuel. Other long-range methods of achieving lower energy use include rationing, altered transportation modes, and major changes in living conditions, standards, and life styles. Implementation of some of these methods would have far reaching impacts on the economy and social patterns of the nation. Even such severe constraints on energy use, however, can be expected only to slow, not halt, the growth in energy requirements in the immediate future.

3) Energy sources are not completely interchangeable. For example: solid fuel cannot be used directly in internal-combustion engines; likewise conversion of the currently dependent coal-burning power plants to an oil-or gas-burning facility is severely limited in the near-term but could be accomplished in the long-term. In addition, such conversion would be costly and perhaps self defeating, because of the oil and gas shortages.

   Although the principal competitive interface between fuels is in electric power plants, the range of flexibility in the choice of fuel after a plant is built is limited by environmental, capital, natural resources, and contractual considerations.

4) A broad spectrum of research and development is being directed to energy conversion--more efficient nuclear

reactors, coal gasification and liquification, liquified natural gas (LNG), and oil shale retorting among others. Several of these should emerge by 1985 as important environmentally acceptable energy conversion systems. The future competitive relationships of these systems to the more conventional energy sources are not yet predictable.

5) Major potentials for filling the supply/demand imbalance for domestic resources are:
   - More efficient use of energy
   - Environmentally acceptable mining, processing, utilizing, and rehabilitation systems that will permit production and use of larger volumes of domestic coal.
   - Accelerated exploration and developments and increased production from all domestic oil and gas resources.
   - Development of the nation's oil shale resources

Of the foregoing, increased domestic oil and gas production offers considerable possibilities, because indicated and undiscovered domestic resources total some 417 billion barrels of oil and 2,100 trillion cubic feet of gas (U.S. Department of the Interior, 1972c, pp. 22, 27). These resources are believed to be producible under current technology. However, the feasibility of providing adequate incentive and reducing the uncertainties inherent in petroleum exploration is not known.

6) The acceptability of oil and gas imports as an alternative is diminished by:

- Expanding costs of foreign over domestic oil.
- Apparent high costs of liquefying and transporting natural gas other than overland by pipeline.
- The security risks inherent in placing reliance for essential energy supplies on politically unstable foreign sources that are prone to interrupt the flow of petroleum in order to exert economic and political pressure on their customers.
- The aggravation of unfavorable international trade and payments balances which would accompany substantial increases in oil and gas imports.

In view of the trends and problems discussed above, it seems reasonable to postulate that for some time to come the best alternative to the production of the coal from the Eastern Powder River Coal Basin of Wyoming would be to produce an equivalent amount of similar coal from elsewhere in Montana, Wyoming, or North Dakota. For a discussion of this alternative, see Coal (Nationwide), in this chapter.

CHAPTER IX

THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

Development of coal resources in the Eastern Powder River Coal Basin of Wyoming will produce a region completely different from that existing at present. Industrial history suggests that changes will develop over time and will be of very long term--for practical purposes, permanent. Volume of coal, development of technology, and economies to be realized from large-scale and long-term operations all support this conclusion. Now the basin is typical of the rural west. Livestock ranching is both the predominant industry and way of life. Limited oil and coal development have not yet changed that. Population is low, and outside Gillette and Douglas, it is sparsely distributed. The land is essentially wild with man's presence apparent only through a few primitive roads, grazing livestock, and fences to control the stock.

Both short-term and long-term development and use of regional resources will change long-term productivity of the basin. From a typical western ranching area, it will be transformed into an industrialized region with mining of coal and its utilization becoming the dominant industry and financial foundation. Man's presence will be abundantly evident. By 1990, 1,540 million tons of coal will have been mined from nearly 14,000 acres and an equal area occupied by roads, railroads, and plants. Man himself will be more numerous with a population increase of 247 percent predicted by 1990. Higher regional income will be accompanied by a new population, many of whom will bring a set of new values in contrast to present values of stability and permanence.

Long-term productivity or quality of the various resources will be affected in different ways. Generally, resources will remain productive but in

a declining trend. There are two principal exceptions to this statement. The first is minerals, the productivity of which obviously is increasing and is expected to remain at a high level for nearly 100 years. The second is the social environment. Since there is no universal agreement on what is "good" or productive, some significant long-term effects will be pointed out without value judgements. Declines will be moderate to 1980 while development is first beginning and will accelerate rapidly over the next five years. After that, response will depend largely on the nature of the particular resource.

Agriculture

Loss of agricultural production will accrue from two sources, loss of land and loss of water. Most of the 29,000 acres of land to be disturbed by 1990 is used for livestock grazing. Long-term productivity of this land will be lowered by 50 percent, or 2,600 animal unit months per year. In addition, 1,245 acres of cropland will be lost. Since there is not a surplus of water within the region to support anticipated development, additional water will be required. One source is acquisition by industry of rights to water now used for irrigation. Some irrigation waters have already been acquired for industrial uses with a corresponding decrease in agricultural productivity. Projected loss of irrigation water to industrial use would result in an estimated additional loss of 31,500 acres of irrigated cropland.

Soil

Long-term productivity of soils in the Eastern Powder River Basin will decline as coal development progresses. Some of this lowered quality will result from accelerated erosion of denuded and disturbed areas. However, by far the greatest loss will result from mixing of soils and burying of better soils in the backfilling and reclamation of coal mines. Soil development is a slow process under the best of conditions; a semiarid climate magnifies the time factor. Loss in soil productivity will be a long-term loss on the 29,000 acres of land disturbed by 1990.

Wildlife

Loss of habitat on 9,500 acres occupied by facilities by 1990 will be permanent. Habitat value on an additional 19,500 acres disturbed by mining, rights-of-way, etc., will be seriously impaired. Adequate habitat will not be restored for antelope, deer and sage grouse for a long-term--20 to 50 years after the area has been disturbed. Figure 7, Chapter V, illustrates the length of time that is required for habitat suitable for certain species to be restored.

Animals in these areas will be lost since normally there are not "unoccupied" areas to support migrant population. By 1990, it is estimated that the base population of deer will have been reduced by 5 percent (850 deer), antelope by 9 percent (2,700 head), and loss of 940 to 1,250 sage grouse.

Perhaps more important over the long term is the effect of increased population and the activity, business and leisure of that population. It is estimated that a total of 116,000 acres of wildlife habitat will have been impaired from increased human utilization. Many animals cannot stand this increased human activity; their habitat is lost on otherwise undisturbed areas. Anticipated loss of 90 elk in the Rochelle Hills and general vicinity of the Atlantic Richfield and Kerr-McGee leases is an example. Most predators will respond similarly.

Long-term wildlife productivity losses may extend well beyond limits of the basin and its development. If water is to be imported, it most likely will come from the Green River in southwestern Wyoming. Construction of a reservoir on the Green River would cause significant habitat (and productivity) loss in that part of the state.

Recreation

Industrial development of the Eastern Powder River Coal Basin will change the nature of the recreation/aesthetic productivity of the area. Present recreation experiences provided are those associated with wild, semi-primitive lands. Both development and the number of people associated with it will change this. Since there will be more people participating there will, in one sense, be more recreation. However, it will not be primitive land based. There also will be more emphasis on urban types of recreation such as swimming pools, golf, playgrounds, etc. Extensive types of recreation will be replaced by more intensive recreational types.

At the same time and for the same reasons, aesthetic values of the region will change. Mines, structures, railroad traffic, and additional vehicle traffic will transform the basin from an area typical of the traditional west to one more representative of industrial civilization. Both local residents and tourists will be affected by this change.

Finally, there will be a diminished recreation land base. As population increases, so do problems of people use. As gates are left open, litter increases, properties are subject to vandalism, more private lands will be posted and closed to public use. Except for sightseeing, recreation productivity of these lands will be effectively lost.

Socio-Economic Conditions

As stated earlier, evaluation of many social and economic effects, both short-term and long, depends a great deal on the personal value systems of the observer. Development of coal and associated industry will provide about 30,000 new jobs in the region by 1990. In addition to more jobs, average income is expected to rise substantially. Coupled with local expenditures by industry, the net result will be a major increase in regional income.

In the short term, all public facilities will be overcrowded or overloaded and the population, particularly previous residents, will suffer. Schools face overcrowded conditions and possibly double sessions. Bussing to less crowded areas may be necessary, and there may be difficulty in recruiting teachers. Health facilities and personnel probably will also be overtaxed in the short term. Water and sewer systems, police and fire departments of both Gillette and Douglas must be expanded to serve expected populations. In the short term, all these constitute a hardship on the persons involved in growth. However, as facilities catch up to the population, more and better services should be available to all. The larger population will be able to support a larger educational system that can offer a greater variety of instruction more nearly meeting needs of more pupils. Similarly, a large population can support hospitals with more complete facilities and a more varied and specialized medical staff.

Not so easily assessed is the change in life styles that will accompany development. In the short term, a conflict between old and new can be expected. A transient attitude can be expected of much of the population, particularly during construction. Accompanying this will be much that goes with a "boom town" attitude. In the long term, these factors will develop into a

mixing and integration of life styles. New types of people will contribute to variety within the community group and a new "community" will result.

CHAPTER X

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Mineral Resources

The major commitment of resources is the mining and consumption of 1.5 billion tons of coal by 1990. This represents 12 percent of the known present economically strippable coal reserves in the Eastern Powder River Coal Basin.

Large amounts of clinker, sand, gravel and other types of aggregate material will be used and for all practical purposes is irretrievable. The total amount to be used in the study area by 1990 is unknown but will be over 1.5 million cubic yards.

In the southern part of the study area, some minor amounts of uranium resources could be irreversibly committed. Commitment would occur to the extent that dilution of mineralized rock during coal mining prohibits recovery.

Water Resources

In areas where the coal or overlying material is saturated, aquifers will be permanently removed by mining.

If large quantities of ground water are pumped from thick Tertiary and Cretaceous age sand and sale aquifers, part of the water will come from shale and there could be some irreversible subsidence. Areas of subsidence would be local and would be restricted to well fields where considerable (several hundred feet) dewatering and draining of the shale beds took place over a period of years.

Although some water will be recycled, such as for cooling purposes, much of the water used for generation of power and for gasification plants will be consumed. By 1990, water use associated with coal development in the area will amount to 49,620 acre-feet per year. The coal slurry pipeline will be removing an estimated 15,000 acre-feet of water annually from the study area.

Cultural Resources

Any destruction of archeological or paleontological values will be an irreversible commitment of resources.

Aesthetics

The present natural state of the study area will be irreversibly and irretrievably committed to change. The change will be one to industrialization which for all intents cannot be reversed once it occurs.

Lost Production

At the present time, production on the railroad route and coal leases is primarily forage and browse utilized by domestic livestock and wildlife. From the assumptions basic to this report and data contained elsewhere herein, it is possible to estimate production losses. It must be emphasized that these figures are rough estimations only.

For purposes of this analysis, the following assumptions were made:

- -35% of coal mined is from an area where a loss of 4.3 acres equals one AUM.
- -65% of coal mined is from an area where a loss of 6.5 acres equals one AUM.
- -No production on disturbed areas.
- -On reclaimed areas 50 percent production loss will occur.

Total areas to be disturbed and reclaimed are shown on Figure 6, Chapter II. The total AUM loss over the period from 1975 through 1990 is 33,200 AUMs* of livestock forage.

By 1990, an estimated 7,100 acres of land will have been removed from productivity by plant facilities, roads, and railroads. Their occupancy should be considered permanent and thus an irreversible and irretrievable commitment of land.

Addition of an anticipated 2,400 acres of residential and commercial development by 1990 would result in an estimated 9,500 acres being irreversibly and irretrievably committed to uses other than presently exist on the land. This change will mean a permanent loss of wildlife habitat and grazing land. Displacement of all animal species from this land will occur.

*AUM -- animal unit month. A measure of forage of feed requirement to maintain one cow or 5 sheep for a period of 30 days.

Loss of Power and Materials Used for Development

Extraction of coal, construction of a railroad and reclamation of disturbed areas will require a commitment of liquid fuels, electric power, manpower, machinery and a myriad of lesser items such as blasting chemicals, paper, seed, etc. This material and effort will be irretrievably lost to other uses. However, to the extent these resources would be employed in energy development elsewhere to meet projected national demands, this commitment to development of Eastern Powder River Coal can be considered in the nature of a transfer rather than an incremental commitment of resources.

Loss of Life

Fatal accidents will occur which are related directly to the physical activity of strip mining coal and are considered on-the-job accidents. Secondary, however, will be a variety of occurrences which will be fatal to human life which occur not because of direct mining activity, but as a result of increased human interaction from population increases. Historical trends for all types of on-the-job fatalities could be cited as they could for a multitude of other fatal occurrences. The point is not so much how many will occur, because projected future fatality rates are at best speculative, but that they historically do occur and they will continue to occur as a result of coal development. An unquestionably irreversible and irretrievable commitment of human resources will be lost due to strip mine accidents, traffic accidents, possible train accidents, murders and suicides. Regardless of the impetus or fault of any of these, they are all irreplaceable losses and there will be more of them than previously occurred in the basin area.

Based on fatal accident rates experienced in the strip mining industry during 1972, the latest figures readily available, an employee will suffer a fatal accident for every 14.3 million tons of coal produced. By 1990, as many as 108 people can be expected to have lost their lives in mining coal. Based on 1972 rates, disabling injuries can be expected to occur at the rate of 9.24 per million man hours worked. Differences in mine method and attention to safety precautions could induce departures from expected rates in the future.

CHAPTER XI

CONSULTATION AND COORDINATION

This is an account of how the EIS interagency team was organized and how it functioned and a discussion of participation by various other organizations.

Organization of interagency task force team for the environmental statement

A January 24, 1974, memorandum from the Office of the Secretary of the Interior assigned the Wyoming State Director, Bureau of Land Management, lead responsibility for preparation of this environmental impact statement. The primary interagency effort involved Bureau of Land Management, U.S. Geological Survey, U.S. Forest Service, and Interstate Commerce Commission. Subsequently, an approach to the project was developed, including selection of team members and scheduling for a multiplicity of actions.

These and other matters were discussed at an interagency meeting on February 6, 1974, at Little America, Cheyenne, Wyoming. The following items were agreed upon at the meeting and, subsequently, implemented during the course of statement development.

a. Six teams were established representing broad categories of environmental concern, including soils and vegetation, range and wildlife, cultural values, socio-economics, hydrology, geology, mining and ecological interrelationships.

b. Four teams were led by BLM specialists and two teams by USGS specialists. USFS agreed to provide support to all teams where activities in the National Grasslands were involved.

c. The EIS teams were housed at the Hitching Post Inn because federal office space that would afford the type of work accommodations needed was not available in Cheyenne. One USGS team had adequate office space in Cheyenne while the other worked out of its offices in Reston, Virginia; Billings, Montana; and Newcastle, Wyoming. The USFS team operated from its offices in Laramie and Douglas Wyoming. All teams worked at the Hitching Post as necessary for effective interagency coordination.

d. The general work schedule was ten days on duty and four days off to afford continual, full-day working relationships. This total effort will represent 27 man-years through September 1974, when the final statement is issued.

e. The teams were comprised of the following scientific and behavioral disciplines: range management, archeology, wildlife biology, geology, mining engineering, hydrology, soils science, landscape architecture, economics, sociology, history, civil engineering, and outdoor recreation. Support skills in the form of cartography, drafting, illustrating, and administrative functions were also utilized. Total team membership averaged more than twenty-five people.

f. BLM provided adminstrative and clerical support to all teams while in residence.

g. Periodic review was provided in Cheyenne by representatives of the Office of Environmental Project Review and Office of the Solicitor, in the Department of Interior, Forest Service, and Interstate Commerce Commission at the Washington level. All

reviews to assess technical adequacy and progress were conducted in Cheyenne.

h. Specialized services to assemble and analyze research materials and to provide consultant assistance were secured by contract.

Preparation of the Draft Environmental Statement

Federal participation

In the preparation of the draft statement, data and/or review comments were solicited from the following bureaus and offices within the Department of the Interior: Bureau of Sport Fisheries and Wildlife, Bureau of Outdoor Recreation, National Park Service, Office of Energy Data and Analysis, Office of Research and Development, Office of Energy Conservation, Office of Oil and Gas, Office of Coal Research, Bureau of Mines, Office of Land Use and Water Planning, Office of Water Resources Research, Bureau of Indian Affairs, Eastern States Office, Office of Environmental Project Review, Office of Solicitor, Bureau of Reclamation, and Assistant Secretaries Office.

Effective coordination has been achieved with National Park Service, Bureau of Outdoor Recreation, Bureau of Reclamation, Bureau of Sport Fisheries and Wildlife, and Office of Coal Research. Letters from these agencies are at BLM's Cheyenne office.

Department of Agriculture agencies contacted were the Forest Service and Soil Conservation Service.

Forest Service personnel participated in preparing the draft statement and, therefore, coordination was effected.

Other organizations involved in review and providing data for the draft statement are: Environmental Protection Agency, Northern Great Plains

Resource Program, and National Advisory Council on Historic Preservation.

Close coordination was achieved with the Natural Historic Preservation Council. Figure 1 is a copy of the letter received from the Council.

State and local government participation

Initially, the Governor of Wyoming was contacted to establish a working relationship with the various state agencies. Consultation and coordination was achieved with the following: Governor's Special Assistant, Office of the Attorney General, Public Service Commission, Federal Relations Office, Recreation Commission, Wyoming Geological Survey, Game and Fish Department, Department of Environmental Quality, Department of Economic Planning and Development, State Archeologist, Department of Agriculture, Commissioner of Public Lands, Water Planning Program Office and State Engineers Office, and Highway Department. Contacts with the Mental Health Consultant to the Wyoming Legislature were also made for data purposes.

Some contacts were made in local communities and with county officials for various kinds of input to the statement. County commissioners expressed interest in the route location of the rail line, under- and overpasses, mine road construction, and traffic expected.

Individuals and city officials from communities throughout the region were contacted for input into the statement.

Close coordination and input was achieved with the Wyoming Game and Fish Department and the State Historial Preservation officer. Figure 2 is a copy of a letter received from Paul Westedt, State Historial Preservation officer.

Advisory Council
On Historic Preservation
1522 K Street N.W. Suite 430
Washington D.C. 20005

May 7, 1974

Mr. Jesse R. Lowe
Acting State Director
Wyoming State Office
Bureau of Land Management
P.O. Box 1828
Cheyenne, Wyoming 82001

Dear Mr. Lowe:

This is to acknowledge receipt of your letter of April 26, 1974, concerning the development of coal resources in the Eastern Powder River Basin which may affect the area's cultural resources.

The Advisory Council now has this matter under review and will be in further contact with you shortly.

We appreciate your cooperation in furnishing us with this material.

Sincerely yours,

Ann Webster Smith

Ann Webster Smith
Director, Office of Compliance

The Council is an independent unit of the Executive Branch of the Federal Government charged by the Act of October 15, 1966 to advise the President and Congress in the field of Historic Preservation.

604 East 25th Street, Cheyenne, Wyo. 82002

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May 8, 1974

Mr. Daniel P. Baker, State Director
U. S. Dept. of the Interior
Bureau of Land Management
P. O. Box 1828
Cheyenne, Wyoming 82001

Dear Mr. Baker:

I have been furnished with certain sections of the preliminary draft of the forthcoming Environmental Impact Statement dealing with the development of energy resources in Wyoming's Powder River Basin. And, as the Wyoming State Historic Preservation Officer, I have been requested to comment thereon.

As the easiest and most practical way of fulfilling a part of that request, both for myself in commenting and for whoever must take note of my observations, I have made a few direct notations here and there on individual pages of sections dealing with history and archaeology. Those sections are, therefore, returned herewith. I have at this time no further comments to make regarding any individual places, features, facts or factors cited in any of them.

It is evident that members of the team drafting this statement were familiar with the laws, orders and implementations governing the proposed industrial developments and protecting the indicated cultural values. While their familiarity with the subject area—both surface terrain and subsurface deposits; both natural features and man-made materialities—is at best sketchy they have, within the allotted time, made a concerted effort to attain greater understanding. Thus, the information they have incorporated into these sections of the statement is almost certainly as good a summary of presently known facts as can be compiled.

However, these sections of the Powder River Basin Energy Resources Environmental Impact Statement are really only improvisations. Tragically, the event of industrial development is already upon the

"Dedicated to the Development of Public Outdoor Recreation"

the scene; it is a necessary event and it will continue along its course. Given that condition, there is no alternative other than making the best use possible out of an improvised contrivance. But, since exploitation of Wyoming energy resources will foreseeingly continue on an expanding scale, there is no justification for duplicating time and again procedures based on inadequate and inferior knowledge—to be forever reacting to a circumstance rather than assimilating the factual understanding whereby guidelines can be established providing for control of future circumstances.

It appears relevant then, within the framework of comments directed on this milepost environmental impact statement, to briefly consider the fundamental reason behind its evident deficiencies.

Historically civilizations have outrun concern for their own heritage. Thought for historic and archaeologic cultural values has lagged many years—even decades and centuries—behind attainment of other benefits. When recognition of such worth has come it has traditionally been the task of the private sector to seek out individual treasures and effect their preservation. This has been voluntary work, always slowed by its very costliness. In fact, even once well started such work by the private sector may well continue to lose ground against the more rapid advance of other factors in the continuing civilization. Against that general background it is not surprising that historic and archaeologic values of the Powder River Basin, a wilderness a century ago and barely an established frontier fifty years ago, are largely unknown or unrecognized today. The same condition holds true for almost all of the young State of Wyoming.

However, this traditional view of any civilization's concern for its cultural heritage is currently undergoing change. Everywhere governments are demonstrating an interest in assisting academic institutions, private societies and individuals in the work of determining and protecting records of the past. Here in America The Congress has enacted two new laws—The National Historic Preservation Act and The National Environmental Protection Act—and the President has made proclamation—Executive Order 11593—designed to strengthen the work of historic preservation in all of its several manifestations. The State of Wyoming has responded by enacting legislation enabling its participation in the national movement.

Under these circumstances it is logical to assume that the work of historic preservation (in all that that term signifies) should by now be well established on a wide basis and already producing significant results. It might even be assumed that those results should have included volumes of data pertinent to the Powder River Basin wherefrom a well founded environmental impact statement might have been expected.

Mr. Daniel P. Baker, State Director
Bureau of Land Management
May 8, 1974
page 3

Unfortunately, laws, orders and regulations are only the first step in a change and cannot in themselves effect that change. The next step is providing appropriations to meet the expenses of the work. That is the part of the currently undergoing change that hasn't as yet progressed very far—with the result that the compilers of the environmental impact statement here in question were hampered by limited data.

Here, finally, I reach the point to be stressed, a point which is pertinent to the purse string holders of both Federal and State Governments. That is that the very energy resources whose industrial exploitation threatens cultural values is easily capable, almost without noticing, of paying the costs of historic and archaeologic preservation. For many years Federal royalties from the production of energy resources out of Federal lands in Wyoming have been astronomical; State revenues from taxes on production of energy resources have also been significantly important. Now, both Federal and State revenues from this source give evidence of constant and exceptional increases. Under these circumstances I submit that both Federal and State Governments would be well advised to provide appropriations sufficient to carry on a truly significant effort toward discovery, investigation and protection of our cultural heritage.

Sincerely,

Paul H Westedt

Paul H. Westedt
Director and Wyoming
State Historic Preservation Officer

PHW:mr

Other participation

During the formulation of the draft statement, many participants were extremely helpful in providing basic input data and recommending alternatives. Mining companies furnishing information were Sun Oil, Atlantic Richfield, Wyodak Resources, American Metals Climax, Kerr-McGee Corporation, Panhandle Eastern Gas Company, Peabody Coal Company, American Nuclear Corp., Wyoming Water, Basin Electric Power Corp., Black Hills Power and Light, Consolidated Coal, Cleveland Cliffs Iron, Decker Coal, Exxon, Gulf Mineral Resources, Homestake Mining, Humble Oil and Refining, Mobile Oil, Montana Dakota Utilities, Northern Natural Gas, Pacific Power and Light, Reynolds Mining, Shell Oil, Teton Exploration, Transco Energy, Union Pacific Mining, Western Standard Corp., Woodward-Envicon, Inc., Cameron Engineers, Continental Conveyor, Ohio Farm Bureau Federation, El Paso Natural Gas, Carter Oil, and Bechtel Engineering Corporation.

Transportation companies contributing were Energy Transportation, Inc., Burlington Northern, Chicago North Western, and Union Pacific Railroads.

Institutional input was received from the University of Wyoming (Black Thunder Project Research Team members), American Museum Natural History, Esso Research and Engineering, Denver Research Institute, Sernco of Denver, Stoltz, Wagner and Brown, VTN Consolidated, Western Interpretive Services, and Dames and Moore.

Coordination and Review of the Draft Environmental Statement leading to preparation of the Final Environmental Statement

Copies of the draft statement were made public on June 1, 1974. Comments were solicited from federal, state and local governmental agencies as well as the public. A listing of the entities from which comments were received is part of the summary located in Volume I of this statement. A further listing of written comments is contained in Volume VI.

In addition to the written comments received, five days of public hearings were conducted beginning on June 24, 1974. Hearings were conducted as follows: 6/24/74 - 7 p.m. - Cheyenne; 6/25/74 - 9 a.m. - Cheyenne; 6/26/74 - 1:30 p.m. - Casper; 6/26/74 - 7 p.m. - Casper; 6/27/74 - 7 p.m. - Gillette; and 6/28/74 - 9 a.m. - Gillette.

Due to the volume of comments received both at the hearings and in writing, a separate volume was required in order to portray adequately the comments and responses thereto. The comments and responses are located in Volume VI of this statement.